University of Alberta

Neuropsychological Impairment and Driving Performance in Dementia

by

Jaye Loree Wald ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education

in

Counselling Psychology

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Abstract

The purpose of this study was to examine the relationships between neuropsychological test scores and driving performance in dementia. Participants were cognitively impaired older adults (n = 112) that included Alzheimer disease (n = 53) , vascular dementia (n = 28) , and mixed cognitive impairments (n = 31) . Control groups included healthy older (n = 50) and younger (n = 30) adults. This study confirmed that the majority of cognitively impaired older adults posed a driving hazard. Healthy older adults and a minority of persons with dementia exhibited little driving risk. The differences between Alzheimer and vascular dementias on neuropsychological and driving measures were small and not statistically significant. It would be premature to rely on the neuropsychological tests used in this study to predict driving ability. In terms of public safety, all older adults with suspected cognitive impairment could be referred for a standardized driving evaluation.

Dedication

To my mom, Dale, and Harvey

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CHAPTER 1

INTRODUCTION

Statement of the Problem

Progressive dementia is a general syndrome, which encompass a cluster of neurological disorders that cause cognitive impairments. The Diagnostic and Statistical Manual of Mental Disorders (4th ed.) (DSM-IV) criteria for a dementia includes memory impairments and one or more symptoms of aphasia, apraxia, agnosia, or deficits in executive functioning (American Psychiatric Association, 1994; see Parks, Zec, & Wilson, 1993 for a review) . These deficits follow a course of deterioration that results in loss of functioning (American Psychiatric Association, 1994) .

The older adult population, over 65 years old, is the fastest growing age group in our society, and as a consequence, progressive dementias such as Alzheimer and vascular dementias are significantly rising (Bachman, et al. , 1993; Evans et al. , 1989; Fowles, 1990; Hendrie, 1997; Ott et al. , 1995; Terry & Katzman, 1992) . In Canada, 11% of adults between 75 and 84 have dementia, and the prevalence increases to 34% of persons over 85 (Canadian Study of Health and Aging Working Group, 1994) .

One important issue pertaining to older adults is driving competency. Increased crash risk is associated with advancing age, and can be caused by illnesses such as dementia, which affect cognitive functioning (Campbell, Bush, & Hale, 1993; Cooper, Tallman, Tuokko, & Beattie, 1993; Drachman & Swearer, 1993; Dubinskey, Williamson, Gray, & Glatt, 1993; Foley, Wallace, & Eberhard, 1995; McCloskey, Koepsell, Wolf, & Buchner, 1994; Wallace, 1997) . Older adult drivers involved in motor vehicle crashes are more likely to sustain serious injury or death (Carr, 1997; McCoy, Johnston, & Duthie, 1989) .

Conversely, many older adults and a significant number of individuals with early stage dementia pose no driving risk (Dobbs, 1997; Friedland, et al. , 1988; Hunt, Morris, Edwards, & Wilson, 1993; Rizzo, Reinach, McGehee, & Dawson, 1997) . Since a

significant number of older adults rely on driving for transportation, convenience and independence, age, medical diagnosis, or both, should not be used as criteria to revoke driving privileges (Bylsma, 1997; Friedland, 1997; Kingston, Reuben, Rogowski, & Lillard, 1994, Johansson & Lundberg, 1997; O'Neill, 1997; Owsely, 1997) .

Currently, there are no standardized criteria to base driving recommendations upon. Decisions regarding driving competency are usually made by physicians, who have limited validated tools to base recommendations in cases of mental decline (Drickamen & Marottoli, 1993; Miller & Morley, 1993; O'Neill, 1992) . Neuropsychological testing, even without empirical validation, are often included in comprehensive driving evaluations. As a consequence, the development of empirically-based criteria for determining driving competency is viewed as desirable (Dobbs, 1997; Johansson & Lundberg, 1997; Odenheimer et al. , 1994; Owsely, 1997; Wallace, 1997) .

Although a significant body of research has examined cognitive impairment in dementia, the relationship between neuropsychological test findings and driving ability has received far less attention. Although several studies have investigated patterns of neuropsychological impairment and driving in healthy older adult or dementia samples (Avolio, Kroeck, & Palmek, 1985; Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Fitten et al. , 1995; Hunt, et al. , 1993; Owsely, Ball, Sloane, Roenker, & Bruni, 1991; Parasuraman & Nestor, 1991; Rebok, Keyl, Bylsma, Blaustein, & Tune, 1994; Rizzo et al. , 1997) , a clear understanding of these relationships has not emerged.

Overview of Study

Objectives

The purpose of this thesis is to examine the relationships between several neuropsychological test scores and performance-based driving scores and to identify variables that are highly associated and predictive of driving ability. A documentation of the relationships between neuropsychological test scores and driving ability will be very useful for clinicians who are placed in a position of having to provide driving recommendations (Dobbs, 1997; Drickaman & Marottoli, 1993; Fitten et al. , 1995; Rizzo et al. , 1997) . Eventually, with further research, neuropsychological variables that predict driving could be developed into a quick and cost-effective screening tool to indicate driving risk. This study has many strengths. These include a large sample, a broad range of neuropsychological tests, and driving measures from a validated road test.

Plan of Study

This thesis focuses on neuropsychological variables and driving competency in dementia. Specifically, this study examines relationships between several neuropsychological and driving test scores based on previously collected data at the Neurocognitive Research Unit, Northern Alberta Regional Geriatric Program (NARGP) at the Glenrose Rehabilitation Hospital, Edmonton, Alberta. Neuropsychological test variables will be chosen from a comprehensive neuropsychological battery that assessed attention, executive functioning, memory, language, intellectual functioning, visual-spatial, and motor skills. In this thesis, decisions to include particular tests will be based on prior research findings (Fitten et al. , 1995; Hunt et al. , 1993; Parasuraman & Nestor, 1991; Rebok et al. , 1994; Rizzo et al. , 1997) , and availability and completeness of neuropsychological test data. Driving performance data will be obtained from a validated on-road evaluation developed at the Neurocognitive Research Unit (Dobbs, 1997) .

Format of Thesis

This thesis consists of four chapters: Introduction, Paper I, Paper II, and Summary. The Introduction includes a statement of the problem and intent of the research study. Paper I examines differences between cognitively impaired participants, healthy older, and young controls on neuropsychological and driving performance measures. Paper II investigates patterns of neuropsychological and driving impairments within the cognitively impaired group, consisting of Alzheimer disease, vascular dementia, and mixed cognitively impaired older adults. The Summary synthesizes the research findings of both papers in consideration of their hypotheses. Limitations, delimitations and suggestions for future research are also discussed. An appendix contains the correlation analyses results from Paper I.

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CHAPTER 2

PAPER I

Neuropsychological Impairment and Driving Performance in Dementia

Background

Increased crash rates are reported in the population of drivers over 65 years old (Cerelli, 1989; O'Neill, 1992; Williams & Carsten, 1989) . Crash risk in older adults is attributed to age-related illnesses, such as dementia, which affect cognitive functioning (Cooper, Tallman, Tuokko, & Beattie, 1993; Drachman & Swearer, 1993; Friedland et al. , 1988; Lucas-Blaustein, Filipp, Dungan, & Tune, 1988; Trobe, Waller, Cooke-Flannagan, Teshima, & Bieliauskas, 1996) . Older drivers involved in motor vehicle accidents are more likely to sustain serious injury or death (Carr, 1997; McCoy, Johnston, & Duthie, 1989) .

The issue of crash risk in older drivers is of pressing concern. The population over 65 years old, is the fastest growing age group in our society. By the year 2020, Fowles (1990) projected there will be over 52 million adults over 65 years old in the United States, many of whom will still be driving (Barr, 1991; Owsley, 1997; Waller, 1991) . Accompanying this increasing population will be a continued rise in the number of cases with progressive dementia (Bachman et al. , 1993; Canadian Study of Health & Aging Working Group, 1994; Evans et al. , 1989; Hendrie, 1997; Terry & Katzman, 1992) . A significant number of older drivers will be afflicted with a dementing illness. This poses serious public health and safety concerns.

One simplistic solution would be to revoke driving licenses past a certain age. However, the statistics of increased crash risk in older persons do not apply to all older drivers. Many older adults, and even some with early stage dementia, pose no increased driving risk (Dobbs, 1997; Hunt, Morris, Edwards, & Wilson, 1993; Rebok, Bylsma, Blaustein, & Tune, 1994; Rizzo, Reinach, McGehee, & Dawson, 1997) . Furthermore,

many older persons rely on driving for transportation and independence (Friedland, 1997; Johansson & Lindberg, 1997; Owsley, 1997) . Therefore, it would be unethical to revoke driving privileges based on age, medical diagnosis, or both. The difficult decisions regarding driving competency should be based on valid and standardized competence evaluations (Bylsma, 1997; Carr, 1997; Dobbs, 1997; Johansson & Lindberg, 1997; Owsley, 1997; Wallace, 1997) .

To address the issue of driving competency in older adults, a number of studies have recently emerged in the literature. Methods of assessing driving fitness have included driving simulators (Bylsma, 1997; Rizzo et al. , 1997) , on-road testing (Dobbs, 1997; Hunt et al. , 1997; Oddenheimer et al. , 1994) , retrospective driving reports (Trobe et al. , 1996) , self-reports (Drachman & Swearer, 1993) , or some combination (Fitten et al. , 1995) . Many clinicians include neuropsychological assessments to assess cognitive impairments as part of a comprehensive driving evaluation. However, little is known about the relationships between various neuropsychological test findings and driving performance. Identifying these relationships would be useful to clinicians in making objective driving recommendations. Eventually, it is hoped that one can find neuropsychological tests that are highly predictive of driving ability (Carr, 1997; Dobbs, 1997; Fitten et al. , 1995; Rizzo et al. , 1997) .

Several research studies have attempted to identify neuropsychological variables that contribute to driving performance. Driving involves many neuropsychological functions, particularly visual attention, executive functioning and visual-spatial skills (Avolio, Kroeck, & Palmek, 1985; Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Parasuraman & Nestor, 1991; Rizzo et al. , 1997) . However, a clear understanding of the relationships between neuropsychological variables and driving performance has not emerged.

The majority of driving research have involved pilot studies with small sample sizes. The sample reported in a study by Hunt et al. (1993) included 13 healthy older

adults, 12 patients with very mild Alzheimer disease, and 13 patients with mild Alzheimer disease. A study by Rebok et al. (1994) included 10 subjects with Alzheimer disease patients and 12 healthy older adults. Twenty-one patients with Alzheimer disease and 18 healthy older adults were evaluated in the study by Rizzo et al. (1997) . To date, only a limited number of neuropsychological tests have been included in driving studies. Four neuropsychological tests were used in the driving study by Rebok et al. (1994). The study by Rizzo et al. (1997) included 12 neuropsychological tests, Hunt et al. (1993) evaluated 10 neuropsychological tests, and Fitten et al. (1995) examined two neuropsychological tests.

The objective of this study is to investigate the differences between three groups: (a) a group of cognitively impaired older adults; (b) a group of healthy older adults; and (c) a young adult control group on a number of neuropsychological and driving variables. It is expected that overall the cognitively impaired group will exhibit greater levels of impairment on neuropsychological and driving measures than control groups. As previous research (Ball & Owsley, 1991; Ball et al. , 1993; Hunt et al. , 1993; Parasuraman & Nestor, 1991; Rebok, et al. , 1994; Rizzo et al. , 1997) has suggested, it is also hypothesized that visual-spatial skills, attention, and executive functioning will be strongly related to driving performance. To set limits on the scope of this paper, no specific hypotheses regarding differences in performance between control groups will be examined. However, results of their performances will be discussed in the context of the other hypotheses.

Method

Participants

From an existing database, a total of 192 participants were included in this study. The sample consisted of 112 cognitively impaired older adults (77 males, 35 females) , 50 healthy older adults (27 males, 23 females) , and 30 healthy young adults (10 males, 20 females) . At the time of the assessment, all participants were currently driving. Ethical

approval for the research study was obtained from the Caritus Health Group, Edmonton General Hospital and University of Alberta, Edmonton, Alberta. Written consent was obtained from all participants, or caregivers where appropriate.

Cognitively Impaired Group. The cognitively impaired group was composed of 53 Alzheimer disease, 28 vascular dementia (multi-infarct dementia) , 4 mixed Alzheimer and vascular dementia, 18 "other cognitive impairments" , and 9 "other medical conditions". The category of "other cognitive impairments" included alcoholic dementia, frontal lobe dementia, head injury , neurotoxic exposure, and normal pressure hydrocephalus. Medical conditions included diabetes mellitus, depression, Parkinson's disease, and other psychiatric disorders. Many of these conditions are also known to cause cognitive deficits that may increase crash risk (see Wallace, 1997) . The diagnosis of dementia was made by a clinical neuropsychologist or psychologist using Diagnostic and Statistical Manual of Mental Disorders (4th. ed.) (DSM-IV) criteria (American Psychiatric Association, 1994) . Participants recruited for this group were referred by physicians to a clinical driving consultation at the Northern Alberta Regional Geriatric Program (NARGP) at the Glenrose Rehabilitation Hospital located in Edmonton, Alberta. All referred patients were asked to participate in the study.

Control Groups. Control group participants were recruited to participate through community advertisements. All participants were screened for medical conditions including neurological and psychiatric disorders. No medical conditions likely to affect cognitive performance were reported by the older control group. One subject in the young control group had non-specified psychiatric difficulties and another reported a non-specified neurological condition. All participants received assessments by Rehabilitation Medicine, Neuropsychological Testing, and Driving Evaluations at the Glenrose Rehabilitation Hospital and NARGP. None of the participants in the control groups performed out of the normal range.

Instruments

Neuropsychological Testing. The neuropsychological tests were administered by a psychological assistant under the direction of a neuropsychologist or clinical psychologist. The neuropsychological testing consisted of several measures commonly used in the assessment of dementia (see Parks, Zec, & Wilson, 1993; Strauss & Spreen, 1991) and in driving (Ball & Owsley, 1991; Ball et al. , 1993; Hunt et al. , 1993; Hunt et al. , 1997; Parasuraman & Nestor, 1991; Rebok, et al. , 1994; Rizzo et al. , 1997) . These tests assessed a wide range of abilities including attention, executive functioning, verbal ability memory, visual-spatial/visual-constructional skills, and motor skills.

All of the measures used in this study are outlined in Table 2-1. Attention was assessed by Trail Making A (TMTA) (Halstead, 1947; Retain & Wolfson, 1985) and an Orientation task to person, place and time (ORIENT) developed at the Glenrose Rehabilitation Hospital. Trail Making Test B (TMTB) (Halstead, 1947; Retain & Wolfson, 1985) , Stroop Test (STROOP) (Golden, 1978, Stroop, 1935) , and Alternating Movements Test (AMT) (Luria, 1966) were included to measure executive or "frontal" functioning. Digit Span Forward (DSF) and Backward (DSB), from Wechsler Memory Scale-Revised (WMS-R) (Wechsler, 1945, 1987) , were included as tests of immediate memory. Immediate, short-term, and long-term verbal memory were evaluated by the California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan, & Ober, 1987) . Continuous Visual Memory Test (CVMT) (Trahan & Larrabee, 1988) and Rey-Osterrieth Complex Figure Test Immediate (30 seconds) (REY-I) and Delayed (20 minute) (REY-D) Recall (Osterrieth, 1944; Lezak, 1989; Rey, 1944) were used to assess visual memory. The copy portion of REY (REY-C), Block Design (BLOC) , and Picture Completion (PICT) of the Wechsler Adult-Intelligence Scale-Revised (WAIS-R) (Wechsler, 1945, 1981) were added as visual-spatial measures. Vocabulary test (VOC) of the WAIS-R was used to measure general verbal ability. Motor skills were evaluated by Finger Tapping Test (FTT) (Halstead, 1947; Retain & Wolfson, 1985) . Further description of administration, scoring

and psychometric properties of these tests can be obtained in their manuals, as well as from Lezak (1983) and Spreen & Strauss (1991) .

Table 2-1

Description of Neuropsychological Tests

Test	Acronym	Function assessed	References
Orientation Task	ORIENT	attention, orientation to person, place, and time	Glenrose Rehabilitation Hospital, Edmonton Alberta
Trail Making Test			Halstead (1947)
Part A	TMTA	visual attention, visual scanning	Retain & Wolfson (1985)
Part B	TMTB	executive functioning (visual planning, sequencing)	
Stroop Color & Word Test	STROOP	executive functioning (cognitive flexibility, response shifting)	Golden (1978) Stroop (1935) Spreen & Strauss (1991)
Alternating Movements Test	AMT	executive functioning (motor planning, sequencing)	Luria (1966)
Digit Span			Wechsler Memory Scale-Revised (Wechsler, 1945, 1987)
Forward	DSF	immediate verbal memory	
Backward	DSB	immediate verbal memory, mental control	
Vocabulary	VOC	general verbal ability, semantic memory	Wechsler Adult Intelligence Scale-Revised (WAIS-R) Wechsler (1945, 1981)
California Verbal Learning Test	CVLT	immediate, short-term, long term verbal memory	Delis, Kramer, Kaplan, & Ober (1987)
Continuous Visual Memory Test	CVMT	visual-spatial memory	Trahan & Larrabee (1988)
Rey-Osterrieth Complex			Lezak (1988)

Figure Test			Osterrieth (1944) Rey (1941)
Copy	REY-C	visual-spatial/constructional abilities	
Immediate Recall	REY-I	visual-spatial short term memory	
Delayed Recall	REY-D	visual-spatial long term memory	
Block Design	BLOC	visual-spatial/constructional abilities	WAIS-R (Wechsler, 1945, 1981)
Picture Completion	PICT	visual-spatial abilities, visual discrimination	WAIS-R (Wechsler, 1945, 1981)
Finger Tapping Test	FTT	fine motor control, manual dexterity	Halstead (1947) Retain & Wolfson (1985)

Driving Measures. Six driving variables from a standardized on-road driving evaluation developed at NARGP were used in this study (see Dobbs, 1997) . These included error scores, Hazard Pass/Fail (HAZ) , Points Pass/Fail (POI) , and driver rating scores, Accident Risk Rating (ACC) , Global Rating (GLOB) , Defensive Driving (DEF) , and Driver Skill (DRIV) . These measures are outlined in Table 2-2. Further description of the standardized road test and vehicle are described by Dobbs (1997) . Briefly, the driving test involved a 45 minute drive, consisting of 37 standardized maneuvers frequently implicated in crashes of older drivers. The road course included a standardized route including residential, light business and urban freeway. An automatic mid-size, dual brake car was used for the road test. The driving evaluator was an experienced certified driving instructor.

Both HAZ and POI were dichotomous variables which resulted in either pass (0) or failure (1) . HAZ, developed by Dobbs (1997) , has been shown to effectively discriminate between normal and cognitively impaired older drivers. This score included "hazardous" or "potentially catastrophic" driving errors that would likely have resulted in an automobile crash if the evaluator had not taken control or adjusted the traffic conditions. Examples of HAZ would be stopping at a green light or driving the wrong way on a freeway. With regard to scoring, an examinee who made one or more HAZ errors was failed. POI, also

developed by Dobbs (1997) , is also an empirically-based score, that includes driving errors for which the frequency and severity of those errors discriminates between cognitively-impaired and normal drivers. The criterion for failure is norm-based.

The driving examiner also provided driver rating scores on ACC, DEF, DRIV, and a composite global score (GLOB) . ACC scores ranged from one to ten (1 = highest accident risk, 10 = lowest accident risk) . DEF scores ranged from one to five (1 = no difficulties, 2 = minor difficulties, 3 = moderate difficulties, 4 = severe difficulties, 5 = very severe difficulties) . Because DEF scores were ordered in the opposite direction from the other scales, they were reversed for the data analysis to make interpretation less confusing (1 = very severe difficulties, 2 = severe difficulties, 3 = moderate difficulties, 4 = minor difficulties, 5 = no difficulties) . DRIV scores ranged from one to five (1 = very poor, 2 = poor, 3 = average, 4 = above average, 5 = excellent) . GLOB scores were derived from the other driver rater scores (less than 11 = unsafe to drive, 11 to 12.5 = borderline pass, 13 or greater = no evidence of safety risk) . Since a factor analysis of these scores had shown all three variables loaded on a single factor (.94 or greater) and this factor accounted for 90.6% of the variance, ACC, DEF, and DRIV were linearly combined to form the GLOB score.

Table 2-2

Description of Driving Performance Measures (Dobbs, 1997)

Driving measure	Acronym	Description
Hazard Pass/Fail	HAZ	error score, hazardous or potentially catastrophic errors, Pass (0) , Fail (1)
Points Pass/Fail	POI	error score, discriminates among young, old, and dementia groups based on number and severity of errors Pass (0) , Fail (1)
Accident Risk	ACC	driver rating score of accident risk (10 point scale: 1 = highest accident risk, 10 = lowest accident risk)

Global	GLOB	driver rating score, based on a linear combination of ACC, DEF, and DRIV (less than 11 = unsafe to drive, 11 - 12.5 = borderline pass, 13 or greater = no evidence of safety risk)
Defensive Driving	DEF	driver rating score of defensive driving (5 point scale: 1 = very severe difficulties, 2 = severe difficulties, 3 = moderate difficulties, 4 = minor difficulties, 5 = no difficulties)
Driver Skill	DRIV	driver rating score of driving skill (5 point scale: 1 = very poor, 2 = poor, 3 = average, 4 = above average, 5 = excellent)

Statistical Analyses

Since subjects received different neuropsychological batteries there were considerable missing data across 159 neuropsychological variables in the database ranging from zero to 100% . To address this problem, it was decided a priori, to exclude variables with 10% or more of missing data. As an extra precaution, a listwise deletion procedure in SPSS statistical software (Version 6.1) was used for all statistical analyses. Although a number of subjects were lost as a result, it was more important to ensure groups remained intact across variables. Making the groups consistent was necessary to accurately compare results across analyses. The original database from which the data was analyzed for this study consisted of 150 cognitively impaired subjects, 56 older adult, and 30 young control subjects. After the listwise deletion procedure, the resulting sample size included 112 cognitively impaired, 50 older adult, and 30 young control subjects.

Prior to the statistical analyses, the data were examined for non-normal distributions, outliers, and errors of coding. The normality of the distributions were visually checked by stem-and-leaf displays. Outliers were also examined by determining the extreme values of each variable. Impossible scores that fell out of the score range for a given test were removed. The remaining extreme values which appeared to be valid were not excluded.

To compare performances of groups on neuropsychological and driving measures, a series of one-way analysis of variance (ANOVAs) were performed. Levene's Test of

Homogeneity was used to evaluate the assumption of homogeneity of variance for each ANOVA. When the statistical software package was unable to perform Levene's test where the sum of the caseweights was less than the number of groups, Hartley's F_{max} was used. In cases when homogeneity of variance was violated, the Brown-Forsythe ANOVA modification (F^*) was calculated (Brown and Forsythe, 1974) . To identify which means differed, post hoc Tukey tests for unbalanced designs were conducted (Kramer, 1956; Smith, 1971) . With expected problems of heterogeneous variances, as well as non-normal distributions, a conservative post-hoc test and a stringent alpha level of .01 were chosen to reduce Type I errors (Glass and Hopkins, 1996) .

To examine relationships between neuropsychological and driving variables, Pearson's product-moment or point-biserial correlations were performed, depending on the nature of the variable. For descriptive purposes guided by previously reported correlations between neuropsychological and driving scores, a correlation of .50 or greater was considered a strong correlation, .30 to .49, a moderate correlation, and .29 or less, a weak correlation. The rationale for reporting correlations in this way is based on a similar study by Hunt et al. (1993) . They reported correlations ranging from .19 to .68 between neuropsychological test scores and on-road driving performance in older adults. Similar results in this study are expected.

Multiple regression analyses were slightly more problematic to deal with because of missing data. Even with the listwise deletion procedure, there was no guarantee subjects in the correlation analyses and ANOVA would be the same as in the regression analysis. For example, using five neuropsychological variables to predict the global driver rating score involved 136 subjects from the cognitively impaired group versus 112 cognitively impaired subjects in the correlation analyses and ANOVA. In the old control group, using five neuropsychological variables to predict the global driver rating score involved 68 subjects from the old control group versus 50 older control subjects in the correlation analyses and ANOVA. The missing data problem precluded more extensive regression analyses as it

would be difficult to draw conclusions. Fluctuating sample numbers would have made it difficult, if not impossible, to compare results across analyses with different variables.

However, for exploratory purposes, two multiple regression models were produced. These model included neuropsychological test scores (independent variables) which correlated the strongest with the Global driver rating score (dependent variable) in the cognitively impaired group and older control group. By inspecting the contribution of the independent variables, the strongest predictors of driving and the amount of variance was accounted for can be determined. An alpha level of .05 was chosen as the level of statistical significance for all analyses except post hoc comparisons.

Results

Demographic Information

As shown in Table 2-3, cognitively impaired subjects had a mean age of 72.71 (SD = 9.12) and a mean educational level of 10.97 (SD = 3.98) years. Age in this group ranged from 43 to 92 years old, 96% were right hand dominant, and 69% were males. The dementia severity based on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) of subjects from the original database (N = 150) was 23.57 (SD = 3.69) and the scores ranged from 12 to 30. The older control group had a mean age of 68.84 (SD = 5.78) and a mean educational level of 14.06 (SD = 2.68) years. Age in this group ranged from 47 to 86, 96% were right hand dominant, and 54% were males. Mean age of the young control group was 35.60 (SD = 3.25) and the mean educational level was 15.83 (SD = 2.64) years. In this group, ages ranged from 30 to 41 years, 33% were males, and 93% were right hand dominant. Significant group differences were obtained for age, $F = (2, 189) = 280.68$, $p < .0001$, and education, $F = (2, 189) = 29.23$, $p < .0001$.

Table 2-3

Demographic Variables of Cognitively Impaired, Older Control, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)
Age[a]			
M	72.71	68.84	35.60
(SD)	(9.12)	(5.78)	(3.25)
Education[b]			
M	10.97	14.06	15.83
(SD)	(3.98)	(2.68)	(2.64)
Gender (% Male)	69%	54%	33%
Handedness (% Right)	96%	96%	93%

Note: CIG = Cognitively Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

[a]F (2, 189) = 280.68, $p < .0001$, [b]F (2, 189) = 29.23, $p < .0001$.

Analysis of Variance

Results of the Levene and F_{max} test revealed the assumption of homogeneity of variance was violated at the .05 significance level for many neuropsychological measures. The Brown-Forsythe correction (F^*) was performed on those ANOVA's where homogeneity of variance was violated. In all cases, the corrected F^* made no difference regarding significance of group effects, as compared to uncorrected F-values.

Results of neuropsychological test findings and driving performance measures are presented below with their corresponding tables. The tables include mean raw test scores, standard deviations, uncorrected F-values (df = 2, 189) and post hoc differences for the

cognitively impaired group (CIG) , older control group (OCG) , and young control group (YCG) . One way ANOVA's revealed significant group differences for all driving and neuropsychological variables ($p < .05$ to $p < .0001$) , with CIG exhibiting the overall greatest level of impairment compared to both control groups.

Attention. Table 2-4 provides a summary of the attention measures. On ORIENT, a measure of attention and orientation to place, person, and time, significant group differences were identified, $F = 45.89$, $p < .0001$. The CIG was significantly more impaired than control groups on the ORIENT task. There was not a significant group difference between control groups. Significant differences among groups were also found in TMTA, $F = 26.72$, $p < .0001$, between all groups with CIG performing the poorest.

Table 2-4

Attention in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Orientation Task					
M	17.18	20.76	20.83	45.89***	CIG>OCG,YCG
(SD)	(3.33)	(.48)	(.46)		
Trails Making Test A					
M	72.54	35.56	21.37	26.72***	CIG>OCG>YCG
(SD)	(52.15)	(11.06)	(5.69)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant

differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Executive Functioning. Table 2-5 presents a summary of the executive functioning measures. On the STROOP test, significant group differences were obtained for word, $F = 50.14$, $p < .0001$, color, $F = 8.49$, $p < .001$, and color-word, $F = 59.73$, $p < .0001$, scores. The CIG performed significantly poorer on word, color, and color-word scores than control groups. Older and young control groups performed at a comparable level across all scores and were not significantly different. On TMTB, significant group differences between all groups were observed, $F = 128.95$, $p < .0001$, with CIG, the slowest and YCG, the fastest.

With regard to AMT, significant group differences were found for palm up/palm down, $F = 18.54$, $p < .0001$, clench/extend, $F = 36.04$, $p < .0001$, tapping, $F = 8.14$, $p < .001$, and total, $F = 33.66$, $p < .0001$, scores. Post hoc analysis revealed the CIG performed poorer than control groups on palm up/palm down and tapping scores, whereas control groups did not significantly differ. On clench/extend and total score, significant differences were detected between all groups, with CIG producing the lowest scores, and YCG, the highest score.

Table 2-5

Executive Functioning in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG ($n = 112$)	OCG ($n = 50$)	YCG ($n = 30$)	F value ($df = 2, 189$)	Group differences
Stroop Color & Word Test					
Word					
M	74.22	106.20	104.30	50.14***	CIG>OCG,YCG

(SD)	(24.57)	(15.67)	(15.62)		
Color					
M	63.61	74.80	77.40	8.49**	CIG>OCG,YCG
(SD)	(23.03)	(16.56)	(14.38)		
Color-word					
M	28.70	46.28	43.13	59.73***	CIG>OCG,YCG
(SD)	(10.60)	(10.87)	(7.75)		
Trails Making Test B					
M	224.57	82.58	47.77	128.95***	CIG>OCG>YCG
(SD)	(84.22)	(31.11)	(11.68)		
Alternating Movements Test					
Palm up/palm down					
M	1.28	1.82	2.00	18.54***	CIG>OCG,YCG
(SD)	(.86)	(.44)	(.00)		
Clench/extend					
M	.60	1.10	1.93	36.04***	CIG>OCG>YCG
(SD)	(.81)	(.91)	(.25)		
Tapping					
M	1.40	1.78	1.90	8.14**	CIG, OCG,YCG
(SD)	(.84)	(.62)	(.40)		
Total					
M	3.28	4.70	5.83	33.66***	CIG>OCG>YCG
(SD)	(1.93)	(1.42)	(.46)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

CIG,OCG,YCG = no significant differences ($p > .01$) between groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

General Verbal Ability. The results of VOC, a measure of general verbal ability, is provided in Table 2-6. Significant group differences were found, $F = 55.95$, $p < .0001$, and the CIG performed significantly weaker than control groups ($p < .001$) . No significant differences between control groups were observed.

Table 2-6

Vocabulary (WAIS-R) Performance in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG ($n = 112$)	OCG ($n = 50$)	YCG ($n = 30$)	F value ($df = 2, 189$)	Group differences
M	35.86	55.18	53.90	55.95***	CIG>OCG,YCG
(SD)	(14.12)	(9.31)	(7.52)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Immediate Memory. Table 2-7 provides a summary of test results of immediate memory. Significant group differences were detected on DSF, $F = 12.20$, $p < .001$, and DSB, $F = 27.71$, $p < .0001$. CIG recalled significantly less numbers correctly than control groups on DSF and DSB. The control groups were not significantly different on either

task.

Table 2-7

Immediate Memory in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Digit Span-Forward					
M	6.88	8.34	8.30	12.20***	CIG>OCG,YCG
(SD)	(1.99)	(1.88)	(2.18)		
Digit Span-Backward					
M	4.63	6.80	7.00	27.71***	CIG>OCG,YCG
(SD)	(1.93)	(2.34)	(2.08)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group. CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Verbal Memory. Table 2-8 presents the results of verbal memory performance as measured by the CVLT. Significant group differences ($p < .0001$) between groups were observed in all scores of the CVLT (immediate recall list 1, $F = 96.58$, immediate recall list 5, $F = 149.42$, lists 1-5 total, $F = 161.24$, short delay free recall, $F = 163.91$, short delay cued recall, $F = 137.40$, long delay free recall, $F = 158.35$, long delay cued recall, $F = 150.17$, cued recall intrusions, $F = 29.28$, and free recall intrusions, $F = 19.93$. CIG recalled fewer words on immediate recall, short delay free and cued recall, as well as long delay free and cued recall measures than control groups. Total score for lists 1-5 was

significantly lower for CIG than control groups. The recall errors, free and cued recall intrusion scores, are based on incorrect item responses not on the target list. The CIG produced significantly more cued and free recall intrusion errors than control groups. No statistical difference between OCG and YCG were identified on intrusion scores.

Table 2-8

California Verbal Learning Test Performance in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Immediate recall list 1					
M	2.96	5.64	7.27	96.58***	CIG>OCG>YCG
(SD)	(1.84)	(1.31)	(1.70)		
Immediate recall list 5					
M	5.38	10.36	13.47	146.42***	CIG>OCG>YCG
(SD)	(2.78)	(2.14)	(2.24)		
Lists 1-5 total recall					
M	22.65	43.00	56.07	161.24***	CIG>OCG>YCG
(SD)	(10.75)	(8.99)	(9.34)		
Short delay free recall					
M	2.72	8.38	12.07	163.91***	CIG>OCG>YCG
(SD)	(2.80)	(2.82)	(2.74)		
Short delay cued recall					
M	4.68	9.94	12.90	137.40***	CIG>OCG>YCG
(SD)	(2.88)	(2.57)	(2.45)		

Long delay free recall					
M	2.84	8.88	12.57	158.35***	CIG>OCG>YCG
(SD)	(2.97)	(3.11)	(2.81)		
Long delay cued recall					
M	4.47	9.82	13.47	150.17***	CIG>OCG>YCG
(SD)	(2.97)	(2.59)	(2.43)		
Cued recall intrusion errors					
M	7.80	1.66	.73	29.28***	CIG>OCG,YCG
(SD)	(7.48)	(1.84)	(.94)		
Free recall intrusion errors					
M	5.69	1.70	1.13	19.93***	CIG>OCG,YCG
(SD)	(5.75)	(1.83)	(1.89)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Visual Memory. Results of visual memory performance are presented in Table 2-9. On the CVMT, a visual memory measure, significant group differences were observed for hits, $F = 10.27$, $p < .001$, false alarms, $F = 19.83$, $p < .0001$, d-prime, $F = 32.14$, $p < .001$, and total, $F = 45.43$, $p < .0001$, scores. For the hits score, CIG correctly identified less previously seen items than control groups, whereas the control groups identified a similar number of items and were not statistically different. Total score was a composite score of number of hits added with number of correct recognitions and false alarm score indicated the number of incorrect item responses. On the false alarm and total score,

differences between all groups were identified. D-prime scores are based on a mathematical formula transformation as an indicator of "memory sensitivity" (Trahan & Larabbee, 1988, p. 8) . CIG had a significantly lower score than control groups, but the control groups were not significantly different.

On REY-I and REY-D, other measures of visual-spatial memory, significant group differences were obtained (F = 104.32, F = 102.12, respectively, $p < .0001$) . All groups were significantly different, with CIG performing poorest, and YCG, performing the best.

Table 2-9

Visual Memory in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Continuous Visual Memory Test					
Hits					
M	33.41	37.18	37.90	10.27**	CIG>OCG,YCG
(SD)	(7.40)	(4.09)	(2.63)		
False alarms					
M	25.69	21.98	15.57	19.83***	CIG>OCG>YCG
(SD)	(8.63)	(7.11)	(6.53)		
D-prime					
M	1.05	1.63	1.99	32.14***	CIG>OCG,YCG
(SD)	(.70)	(.51)	(.53)		
Total					
M	61.85	69.40	75.83	45.43***	CIG>OCG>YCG

(SD)	(8.27)	(6.25)	(7.16)		
Rey Osterrieth Complex Figure Recall Test					
Immediate recall					
M	14.80	34.38	47.10	104.32***	CIG>OCG>YCG
(SD)	(12.04)	(11.40)	(13.60)		
Delayed recall					
M	12.30	32.68	44.30	102.12***	CIG>OCG>YCG
(SD)	(12.49)	(11.39)	(13.23)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Visual-Spatial Skills. Table 2-10 provides a summary of visual-spatial performance. Similar to visual-spatial memory tasks, the overall level of impairment was of greater severity in CIG on REY-C, $F = 23.62$, BLOC, $F = 84.65$, PICT, $F = 54.80$, ($p < .0001$) . On REY-C and PICT, the CIG performed significantly poorer than control groups. No significant differences were detected between control groups in REY-C and PICT. On BLOC, significant group differences were obtained between all groups, with CIG having the poorest score, and YCG, the highest.

Table 2-10

Visual-Spatial Skills in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Rey-Osterrieth Complex Figure Copy Test					
M	55.04	64.34	67.40	23.62***	CIG>OCG,YCG
(SD)	(13.56)	(3.39)	(2.03)		
Block Design					
M	13.12	24.76	35.33	84.65***	CIG>OCG>YCG
(SD)	(9.41)	(8.05)	(8.36)		
Picture Completion					
M	8.88	14.12	16.07	54.80***	CIG>OCG,YCG
(SD)	(4.63)	(3.07)	(2.29)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Motor Skills. Results of the FTT, a measure of fine motor skills are provided in Table 2-11. The CIG performed generally worse overall ($p < .0001$) on dominant, $F = 23.07$, and non-dominant, $F = 19.58$, hands. Significant differences between CIG compared to control groups were identified for both hands, whereas control groups performed at a comparable level.

Table 2-11

Finger Tapping Test Performance in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Dominant hand					
M	40.38	47.44	50.84	23.07***	CIG>OCG,YCG
(SD)	(9.81)	(6.82)	(6.45)		
Non-dominant hand					
M	36.52	41.53	45.69	19.58***	CIG>OCG,YCG
(SD)	(8.78)	(5.74)	(6.20)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group. CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Driving Performance. Table 2-12 provides the results of driving performance. As a whole, CIG also performed poorest on driving measures. Significant group differences were obtained for ACC, $F = 72.11$, $p < .0001$, GLOB, $F = 68.97$, $p < .0001$, DEF, $F = 44.40$, $p < .0001$, and DRIV, $F = 51.25$, $p < .0001$. Post hoc analyses identified group differences between all groups on ACC and GLOB. On DEF and DRIV measures, the CIG performed significantly poorer than OCG and YCG. Control groups performed at a comparable level and were not significantly different from each other on DEF and DRIV.

In the CIG, 61% of subjects made a HAZ error. This driving measure was based on making one or more dangerous or potentially catastrophic errors during the road test.

None of the subjects in the control groups made a HAZ error. Also 29% of the subjects in the CIG failed on the POI score and less than 5% of subjects in the OCG and YCG failed. The GLOB score average for the CIG was 9.67 (SD = 3.27) , whereas the average GLOB scores for the control groups were above 13 (no driving risk) . A frequency distribution was also constructed for GLOB. It was determined that 66 subjects in the CIG scored less than 11 (unsafe to drive) , 23 scored in the 11 to 12 range (borderline pass) , and 23 scored in the pass range (13 or more) . In the OCG, only 3 subjects scored in the unsafe range, 10 scored in the borderline range, and 37 scored in the safe range. All of the YCG subjects GLOB scores fell in the pass range.

Table 2-12

Driving Performance in Cognitively Impaired Older Adults, Healthy Older, and Young Control Groups

Variable	CIG (n = 112)	OCG (n = 50)	YCG (n = 30)	F value (df = 2, 189)	Group differences
Hazard Points Pass/Fail					
M	.61	.00	.00	----	-----
(SD)	(.49)	(.00)	(.00)		
Points Pass/Fail					
M	.29	.04	.03	----	-----
(SD)	(.45)	(.20)	(.18)		
Accident Risk					
M	4.38	6.48	7.53	72.11***	CIG>OCG>YCG
(SD)	(1.75)	(.94)	(.82)		

Global Rating					
M	9.66	13.54	15.17	68.97***	CIG>OCG>YCG
(SD)	(3.27)	(1.59)	(1.32)		
Defensive Driving					
M	3.02	3.96	4.27	44.40***	CIG>OCG,YCG
(SD)	(.93)	(.49)	(.47)		
Driver Skill					
M	2.26	3.10	3.37	51.25***	CIG>OCG,YCG
(SD)	(.77)	(.39)	(.37)		

Note. CIG = Cognitively-Impaired Group, OCG = Older Control Group, YCG = Young Control Group.

---- = ANOVA not calculated as HAZ and POI were dichotomous variables.

CIG>OCG>YCG = significant differences ($p < .01$) between CIG, OCG, and YCG.

CIG>OCG,YCG = significant differences ($p < .01$) between CIG and control groups, no significant differences between control groups.

* $p < .005$, ** $p < .001$, *** $p < .0001$, two-tailed.

Correlation Analyses

Separate correlation analyses were performed for the total sample as a whole (N = 192) , CIG, OCG, and YCG to demonstrate patterns of correlations for each group on neuropsychological and driving measures. Inter-correlations between driving measures were also determined for the CIG. Results of these analyses are provided in the appendix. Pearson's product-moment correlations were performed on continuous neuropsychological and driving variables. Point-biserial correlations were used for continuous neuropsychological and dichotomous driving variables, HAZ and POI.

The correlations for the total sample were all statistically significant at the .05 level. Even weak correlations, as low as .15, were statistically significant. The largest

correlations above .60 were between TMTA, TMTB, REY-C, REY-I, REY-D, BLOC, and PICT with GLOB. Overall, these neuropsychological measures were also strongly correlated with DEF, DRIV, and ACC. POI and HAZ scores produced lower correlations with all of the various neuropsychological scores. For POI, correlations ranged from -.01 (color-score of the STROOP) to .48 (palm up/palm down of the AMT) . For HAZ, correlations ranged from -.16 (color score of the STROOP) to -.55 (list 1-5 total of the CVLT) .

Of greatest interest were correlations obtained in the CIG. Identical to the total group, TMTA, TMTB, REY-C, and BLOC were strongly correlated above .50 with GLOB and ACC scores. These highly related neuropsychological tests all required visual attention, visual-spatial, visual-constructional, and executive planning skills. Other studies have also suggested that these abilities are correlated with driving ability (Ball & Owsley, 1991; Ball et al. , 1993; Hunt et al. , 1993; Rebok et al. , 1994; Rizzo et al. , 1997) . Smaller correlations were obtained between neuropsychological tests with HAZ and POI. For POI, correlations ranged from .01 (color-word score of the STROOP, short delay free recall of the CVLT, and REY-C) to .23 (tapping score of the CVLT, dominant hand of FTT, and non-dominant hand of the FTT) . HAZ correlations ranged from .01 (word score of the STROOP and DSF) to -.24 (immediate recall list 1 of the CVLT) . VOC, DSF, DSB, ORIENT, all scores of the STROOP, free and cued recall intrusion recall errors of the CVLT, and false alarms of the CVMT were weakly related to all driving measures.

Overall, weak correlations were produced in the OCG between neuropsychological test scores and driving measures and very few correlations reached statistical significance. The highest correlations with GLOB included color-word score of the STROOP, REY-C, dominant hand of the FTT, and BLOC. However, none of the correlations were above .50. With regard to the YCG, even lower correlations were produced between neuropsychological test scores and driving variables. The vast majority of correlations were less than .20 and none were above .50. Examples of moderate correlations were color

score of the STROOP with POI, ACC, and GLOB as well as d-prime with DEF.

The intercorrelations of the driving measures in the CIG indicated that ACC, GLOB, DEF, and DRIV were strongly correlated with each other (above .80) . HAZ and POI were moderately correlated with one another, and with the other driving measures (above .30) .

Multiple Regression Analyses

In the CIG the five neuropsychological producing the highest correlations with GLOB were TMTA, $r = -.53$, TMTB, $r = -.49$, REY-C, $r = .51$, BLOC, $r = .53$, and PICT, $r = .48$. They were used to build a multiple regression model to predict GLOB driver rating score. The resulting model produced an $R^2 = .39$, $F\ (5, 130) = 16.75$, $p < .0001$, meaning these five measures accounted for almost 40% of the variance in the GLOB score. Table 2-13 presents the variables included in the regression equation, their standardized (β) and unstandardized (B) beta coefficients and t-test scores of the standardized beta coefficients. Of all the independent variables included in this regression model, TMTA, $t\ (134) = -3.38$, $p < .01$, TMTB, $t\ (134) = -2.73$, $p < .01$, and REY-C, $t\ (134) = 2.07$, $p < .05$, produced the largest t-test scores. These three variables were the strongest predictors of GLOB score.

Table 2-13

Multiple Regression of Five Neuropsychological Variables to Predict Global Driver Rating Score in the Cognitively Impaired Group (n=136)

Measure	β	B	t
Trail Making Test A	-.28	-.02	-3.38**
Block Design	1.22	.05	1.36
Trail Making Test - Part B	-.23	-.01	-2.73**

Rey Osterrieth Figure Copy Test	.19	.04	2.07*
Picture Completion	-1.26	-.05	-1.41

Note. R^2 = .39, ($p < .0001$) .

β = standardized beta coefficient, B = unstandardized beta coefficient.

* $p < .05$, ** $p < .01$.

In the OCG, the five neuropsychological variables producing the highest correlations with GLOB were FTT dominant hand, r = .31, REY-C, r = .30, TMTB, r = -.26, color-word score of STROOP, r = .26, and BLOC, r = .25. They were used to build a multiple regression model to predict GLOB driver rating score. The resulting model produced an R^2 = .33, F (5, 62) = 6.02, $p < .001$, meaning the five measures accounted for 33% of the variance in the GLOB score. Table 2-14 provides the variables included in the regression equation, their standardized (β) and unstandardized (B) beta coefficients, and t-test scores of the standardized beta coefficients. Of all the independent variables included in this regression model, FTT dominant hand, t (66) = 2.49, $p < .05$, and REY-C, t (66) = 2.25, $p < .05$, produced the largest t-test scores. These two variables were the strongest predictors of GLOB score.

Table 2-14

Multiple Regression of Five Neuropsychological Variables to Predict Global Driver Rating Score in the Older Adult Control Group (n=68)

Measure	β	B	t
Trail Making Test B	-.07	.00	-.54
Block Design	.23	.04	1.79

Color-Word score (Stroop Test)	.12	.18	-1.07
Rey Osterrieth Figure Copy Test	.25	.12	2.25*
Finger Tapping Test (dom. hand)	.27	.06	2.49*

Note. R^2 = .33, ($p < .001$).

β = standardized beta coefficient, B = unstandardized beta coefficient.

* $p < .05$.

Discussion

This exploratory study compared several neuropsychological tests and driving scores for three groups: (a) cognitively impaired older adults; (b) healthy older adults; and (c) healthy young adults. It was predicted CIG would exhibit an overall greater level of impairment on both neuropsychological and driving variables. It was also hypothesized that visual-spatial, visual-constructional, visual attention, and executive functioning would be strongly related to driving performance.

One-Way ANOVAs of Neuropsychological Tests. Results from one-way ANOVAs revealed CIG had poorer scores across all neuropsychological domains compared to the control groups. These included attention measures (ORIENT and TMTA), executive functioning (STROOP, TMTB, AMT), general verbal ability (VOC), immediate memory (DSF, DSB), verbal memory (CVLT), visual memory (CVMT, REY-I, REY-D), visual-spatial skills (BLOC, PICT, REY-C), and motor skills (FTT).

CIG>OCG>YCG. Post hoc comparisons determined many neuropsychological tests differentiated between all groups with the CIG performing the worst, and YCG, the best. These measures included one measure of attention (TMTA), two tests of executive functioning (TMTB, clench/extend and total scores of the AMT). In agreement with previous reports (Spreen & Strauss, 1991; Wahlin, Blackman, Wahlin, & Winblade, 1996) age-related changes seem to be associated with completion time on TMT (A and B), and performance is adversely affected by dementia (Lafleche & Albert, 1995). No studies on

age-related changes of the AMT could be found to compare results.

Two tests of visual memory (false alarm and total score of the CVMT, REY-I, REY-D) were also detected between all groups. Other reports have also found age-related changes and poorer performances in samples with dementia using the REY-I and REY-D (Berry, Allen, & Schmidt, 1991; Boone, Lesser, Hill-Gutierrez, Berman, & D'Elia, 1993; Chiulli, Hoaland, La Rue, & Garry, 1995) . Other studies on the CVMT also observed that performance is affected by both aging and dementia (Hall, Pinkston, Szalda-Petree, & Coronis, 1996; Trahan, Larrabee, Fritzsche & Curtiss, 1996) . On the CVLT, significant differences were obtained between all groups on all measures except free and cued intrusion recall errors. Findings on the CVLT indicated the CIG had a greater degree of immediate, short-term and long-term verbal memory deficits, had more difficulty learning new verbal information and forgot new verbal memory faster than control groups. It is not surprising these results were obtained, as deficits in verbal episodic memory are one of the defining features of Alzheimer disease (Cullums, Filley, & Kozora, 1995; Delis et al. , 1991; Desgranges, Eustache, Rioux, de la Sayette, & Le chevalier, 1996; Parks et al. , 1993) .

Another test to produce significant differences between all groups was BLOC of the WAIS-R, a measure of visual-spatial/constructional ability. Other studies have also obtained similar findings (Malec, Ivnik, & Smith, 1993; Troyer, Cullum, Munro, Smernoff, & Kozora, 1994; Ruff & Parker, 1993; Steenhuis & Ostbye, 1995) . On the majority of tests where differences were found between control groups, these tasks were timed. Examples include TMTA, TMTB, and BLOC. These findings are consistent with other research which suggests a general slowing of performance on timed tasks with advancing age (Lezak, 1982; Strauss & Spreen, 1991) .

CIG>OCG,YCG. On other neuropsychological tests, the CIG faired much worse than both control groups who performed at a comparable level. This suggests that certain tests are more resistant to the effects of aging, but not to dementia. In agreement with the

findings of this paper, orientation to person, place, or time is not affected by normal aging (Malec et al. , 1993) . No differences were identified between control groups on a few measures of executive functioning (all scores of the STROOP, palm up/palm down score of AMT) . Results of the STROOP are contrary to other findings that suggest a strong aging effect on performance (Graf, Uttl, & Tuokko, 1995; Spieler, Balota, & Faust, 1996; Uttl & Graf, 1997) . These contradicting results may be possibly attributed to methodological and sampling differences.

In agreement with previous research, VOC and general verbal ability remains relatively intact with increasing and is affected more by socio-economic status and education (Malec et al. , 1993; Ryan, Paolo, & Dunn, 1995; Schaie, 1990) . There were no significant differences between control groups on DSF or DSB of WMS-R. Malec et al. (1993) have suggested that DSF, DSB, and VOC are weakly associated with age, and poor performance is related to brain damage or dementia.

The number of cued and free intrusion recall errors of CVLT were not different between control groups . This finding is consistent with that reported by Paolo, Troster, and Ryan (1997) . In contrast to other studies (Hall et al. , 1996; Trahan, et al. , 1996) , no significant differences between control groups were detected on two scores of the CVMT (d-prime and hits). The control groups also performed at a similar level on REY-C, and PICT. Others however, (Chiulli et al. , 1995; Malec et al. , 1993; Spreen & Strauss, 1991) have reported the REY-C and PICT slightly declines with advancing age and dementia. No significant differences between control groups were found on the FTT, whereas other studies have reported this test is sensitive to aging (Leckliter & Matarazzo, 1989; Massman & Doody, 1996) . Contradictory findings of these findings and prior research are likely explainable by differences in samples and methodologies.

<u>One-Way ANOVAs and Description of Driving Performance</u>. Driving measures were obtained from a standardized on-road driving evaluation including error scores of HAZ and POI and driver rating scores of ACC, DEF, DRIV, and GLOB. The most notable

finding was that no control group subject made a HAZ error, whereas 61% of the CIG made this type of error. Also 29% of the subjects in the CIG failed on the POI score and less than 5% of subjects in the OCG and YCG failed. This suggests that cognitively impaired older adults are more likely to make serious and dangerous driving errors. The GLOB score findings also suggested that a significant proportion of the CIG were unsafe to drive. Sixty-six subjects in the CIG obtained a GLOB score in the "unsafe driving" range, 23 fell in the borderline pass range, and 23 fell in the pass range. Only three subjects from the OCG fell in the unsafe range and none of the YCG did. Consistent with previous reports, these findings indicate that driving impairment is common in cognitively impaired older adults (Ball et al. , 1993; Fitten et al. , 1997; Hunt et al. , 1993; Rebok et al. , 1994; Rizzo et al. , 1997) .

Post hoc comparisons identified significant differences between all groups on ACC and GLOB. However, on measures of DEF and DRIV, the control groups performed at a comparable level. The position that older healthy drivers and even a minority with cognitive impairment pose little driving risk was also supported by the findings of this study (Dobbs, 1997; Hunt et al. , 1993; Rizzo et al. , 1997) .

Homogeneity of Variance. The assumption of homogeneity of variance needed for ANOVA was violated for many neuropsychological tests. This required additional statistical corrections to interpret the results accurately. Very high standard deviations occurred primarily in the CIG and to somewhat a lesser extent in the OCG. Examples of rather high standard deviations in the CIG included TMTA (SD = 52.15) and REY-C (SD = 13.56) . In the OCG, the standard deviations for these tests dropped to 11.06 and 3.39, respectively. Even lower standard deviations were produced in the YCG (TMTA, SD = 5.69, REY-C, SD = 2.03) . In addition the ranges of scores were quite large in the CIG and OCG. For example, in the CIG, the range for TMTA was 18 to 363, and for the REY-D, the range was 0 to 56. Hunt et al. (1993) also reported a high standard deviation for TMTA (SD = 23.8) in their sample of older adults, as did Padovani et al. (1995) for the

REY in patients with Alzheimer disease (SD = 24.8) . Other studies have also reported large variability in neuropsychological test results using samples with Alzheimer disease (Desgranges et al. , 1996; Hanninen et al. , 1997; Malec et al. , 1993; Mitrushina, Uchiyama, & Satz, 1995) .

Interestingly, the behavioral driving measures produced much smaller standard deviations and did not violate the homogeneity of variance assumption. For example, the standard deviations for the GLOB score were very low (CIG, SD = 3.27, OCG, SD = 1.59, YCG, SD = 1.32) . In all driving measures, the CIG obtained the highest variability compared to the control groups. The discrepancies in variability between behavioral and neuropsychological measures is a problematic issue in the field of neuropsychological assessment (Moore & Litchenberg, 1996; Wallace, 1997) . The low correlations between neuropsychological test scores and driving measures in the YCG of this study reiterates this concern. Milberg (1996) has also criticized neuropsychological tests for their inability to correspond with everyday functional behavior in older adults.

Correlation Analyses. The purpose of the correlation analysis was to explore the various relationships and patterns of correlations between neuropsychological test findings and driving performance.

The correlations for the total sample (N = 192) were all statistically significant at the .05 level. Even weak correlations, as low as .15, were statistically significant. The largest correlations above .60 were between TMTA, TMTB, REY-C, REY-I, REY-D, BLOC, and PICT with GLOB. Overall, these neuropsychological measures were also strongly correlated with DEF, DRIV, and ACC. POI and HAZ scores produced lower correlations with all of the various neuropsychological scores. For POI, correlations ranged from -.01 (color-score of the STROOP) to .48 (palm up/palm down of the AMT) . For HAZ, correlations ranged from -.16 (color score of the STROOP) to -.55 (list 1-5 total of the CVLT) .

Of greatest interest were correlations obtained in the CIG. Identical to the total

group, TMTA, TMTB, REY-C, and BLOC were strongly correlated above .50 with GLOB and ACC scores. These highly related neuropsychological tests all required visual attention, visual-spatial, visual-constructional, and executive planning skills. Other studies have also suggested that these abilities are correlated with driving ability (Ball & Owsley, 1991; Ball et al. , 1993; Hunt et al. , 1993; Rebok et al. , 1994; Rizzo et al. , 1997) . Smaller correlations, under .30. In particular, VOC, DSF, DSB, ORIENT, all scores of the STROOP, free and cued recall intrusion recall errors of the CVLT, and false alarms of the CVMT were very weakly related to all driving measures.

Overall small correlations were produced in the OCG between neuropsychological test scores and driving measures. Very few correlations reached statistical significance. The highest correlations with GLOB included color-word score of the STROOP, REY-C, dominant hand of the FTT, and BLOC. However, none of the correlations were above .50. With regard to the YCG, even lower correlations were produced between neuropsychological test scores and driving variables. The vast majority of correlations were less than .20 and none were above .50.

The intercorrelations of the driving measures in the CIG indicated that ACC, GLOB, DEF, and DRIV were strongly correlated with each other (above .80) . HAZ and POI were moderately correlated with one another, and with the other driving measures (above .30) .

The heterogeneity of the sample had a strong influence on the differences in correlations obtained across groups, particularly in the total group and CIG. For example, in total sample, the correlation between TMTB and GLOB was $r = -.73$, $p < .001$. In the CIG, the correlation was $r = -.49$, $p < .001$, which dropped to $r = -.26$, $p > .05$, in the OCG, and $r = -.21$, $p > .05$, in the YCG. As another example, in the total sample, the correlation between REY-C and GLOB was $r = .62$, $p < .001$. In the CIG, the correlation was $r = .51$, $p < .001$, which dropped to $r = .30$, $p > .05$, in the OCG, and $r = .06$, $p > .05$ in the YCG.

Multiple Regression Analyses. This study ascertained patterns of highly correlated neuropsychological and driving variables and built two regression models based on those findings. Interestingly, in the CIG, the neuropsychological tests that most highly correlated with GLOB were TMTA, TMTB, REY-C, BLOC, and PICT. The resulting multiple regression model using those five visual-spatial measures accounted for almost 40% of the variance in the GLOB score. Of all the independent variables included in this regression model, TMTA, TMTB, and REY-C were the strongest predictors of the GLOB score. In the OCG, the five neuropsychological variables that were most highly correlated with GLOB were TMTB, color-word score of the STROOP, REY-C, BLOC, and FTT. These variables accounted for approximately 33% of the variance in the GLOB score. The REY-C and dominant hand score of the FTT were the strongest predictors of GLOB . Rizzo et al. (1997) also found that the REY was the strongest predictor of crashes using a driving simulator in subjects with Alzheimer disease. Other strong predictors of crashes in their study were BLOC and TMT.

Advantages and Limitations of Study. This study offered numerous methodological and substantive improvements over previous research. The validated road test variables provided a strong base from which to compare the various neuropsychological instruments. Only a few studies (Dobbs, 1997; Fitten et al. , 1995; Hunt et al. , 1993) have also evaluated driving abilities using a standardized road-test. A statistical correction was used to address the violation of homogeneity of variance that occurred in many neuropsychological variables. In this study, a stringent alpha level of .01 for post-hoc comparisons minimized the risk of Type I errors. Other related studies (Padovani, et al. , 1995; Rebok et al. , 1994) , have used an traditional alpha .05 level. Precautions were also taken to ensure subjects remained consistent across variables in order to make accurate group comparisons.

To date, this was the first driving study to include such a large sample size. Many other driving studies have used smaller sample sizes. The sample reported in a driving

study by Hunt et al. (1993) included 13 healthy older adults, 12 patients with very mild Alzheimer disease, and 13 patients with mild Alzheimer disease. A study by Rebok et al. (1994) included 10 subjects with Alzheimer disease and 12 healthy older adults. Twenty-one patients with Alzheimer disease and 18 healthy older adults were evaluated in the driving study by Rizzo et al. (1997) .

This study incorporated a broad range of commonly used neuropsychological tests. It also included many neuropsychological tests that have not been previously associated with driving performance. These were the CVLT, CVMT, AMT, VOC, DSF, DSB, PICT, and FTT. Many other studies examining patterns of neuropsychological impairment and driving performance in older adults have used smaller neuropsychological batteries. Four neuropsychological tests were used in the driving study by Rebok et al. (1994). The study by Rizzo et al (1997) included 12 neuropsychological tests, Hunt et al. (1993) evaluated 10 neuropsychological tests, and Fitten et al. (1995) included two neuropsychological tests.

A shortcoming of this study pertains to group composition. It may have been helpful to include a higher number of males in the YCG and a higher number of females in the OCG. Increasing gender representation in these groups would have provided a more inclusive database. This is important when using ANOVA, as gender is a demographic factor known to affect neuropsychological test scores.

Recommendations for Future Research. Emerging from this study were a number of recommendations for future research to consider. Replication of this study with similar variables with a comparable sample would add confidence to the conclusions drawn in this study with regard to the relationship between neuropsychological test scores and driving performance. As a precaution proceeding research using ANOVA should always check the assumption of homogeneity of variance. It would be of considerable interest to examine specific sub-groups within the cognitively impaired group, such as Alzheimer disease and vascular dementia. This may foster a better understanding of within group differences for the CIG. Dobbs, (1997) , Fitten et al. (1995) , Rebok et al. (1994) , and Rizzo et al.

(1997) , have advocated the development of empirically based driving evaluations which include cognitive screening tools that predict driving risk. Before neuropsychological screening protocols for driving competency can be developed, research may need to address the fundamental issues of reliability and validity in geriatric neuropsychological assessments (see Milberg, 1996; Wallace, 1997) .

Conclusion. Sixty-one percent of the CIG made a hazardous or potentially catastrophic driving error during the road test. A disconcerting finding of this study was that all participants in the CIG were driving at the time of the study. These results suggest that many cognitively impaired older adults who drive, present a potential driving hazard. No subjects from the control groups made such an error. These findings also indicate that healthy older adults and even a small proportion of older adults with cognitive impairments pose little driving risk. On all neuropsychological tests, the CIG exhibited a greater level of impairment than control groups. Of all the neuropsychological tests, visual-spatial, visual attention, and executive functioning tasks appeared to be associated with driving in the CIG. However, it would be premature to rely on the neuropsychological instruments reviewed in this study to make decisions regarding driving competency. In terms of public safety, all older adults with suspected cognitive impairment could be referred for a standardized performance-based driving evaluation .

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CHAPTER 3

PAPER II

Neuropsychological Impairment and Driving Performance in Alzheimer and Vascular Dementia

Background

Advancing age is associated with an increased risk of developing serious medical conditions. Of particular concern is the rising prevalence of dementia (Bachman et al. , 1993; Canadian Study of Health & Aging Working Group, 1994; Evans et al. , 1989; Terry & Katzman, 1992) . Alzheimer disease is the most frequently occurring dementia. It develops in 10.3% to 11.3% of adults over 65 years of age, and increases with advancing age (Evans et al. , 1989; Hendrie, 1997; Ott et al. , 1995) . The second most common dementia is vascular dementia. It occurs in 1.2% to 4.2% of adults over 65 years of age (Hebert & Brayne, 1995; Ott et al. , 1995) . Both illnesses are associated with multiple cognitive impairments that affect everyday functioning and independent living (American Psychiatric Association, 1994) . Together, the prevalence of these dementias create enormous health care costs and have devastating effects on afflicted individuals and their families.

One important issue facing older adults is driving competency. Many drivers continue driving into advanced age and the proportion of older drivers is increasing (Barr, 1991; Waller, 1991) . This occurrence is a concern because increased crash risk is associated with older adults drivers (Cerelli, 1989; O'Neill, 1992; Williams & Carsten, 1989) . In this population, diminished driving ability is likely caused by a dementia that compromises cognitive functioning (Cooper, Tallman, Tuokko, & Beattie, 1993; Drachman & Swearer, 1993) . Furthermore, older drivers involved in motor vehicle accidents are more likely to sustain severe injury or death compared to their younger counterparts (Carr, 1997; McCoy, Johnston, & Duthie, 1989) .

Driving competency in older adults needs to be based on standardized driving

evaluations and many agree that decisions regarding driving cessation should be made on an individual basis (Carr, 1997; Dobbs, 1997; Johannson & Lundberg, 1997; Odenheimer et al. , 1994; Owsley, 1997; Wallace, 1997) . Since many older adults, and even some persons with early stage dementia pose no driving risk, age or medical diagnosis are not valid criteria for revoking driving privileges (Carr, 1997; Dobbs, 1997; Friedland et al. , 1988; Hunt, Morris, Edwards, & Wilson, 1993; Rizzo, Reinache, McGehee, & Dawson, 1997) . However, little is known about other factors that contribute to driving performance.

Previous research has primarily investigated the effects of Alzheimer disease on driving ability (Fitten et al. , 1995; Hunt et al. , 1993; Rebok, Keyl, Bylsma, Blaustein, & Tune, 1994; Rizzo et al. , 1997) . There is general consensus that driving remains relatively intact in the early stage of the disease but becomes increasingly impaired as the disease progresses (Drachman & Swearer, 1994; Hunt et al. , 1993; Rebok et al. , 1994) . To date, virtually nothing is known how other age-related dementias, such as vascular dementia, affect driving performance. The study by Fitten et al. (1995) is only existing research to compare Alzheimer disease and vascular dementia. These authors reported that subjects with mild vascular dementia were less impaired and exhibited greater variability on driving variables than subjects with early stage Alzheimer disease.

A clear understanding of the relationship between driving performance and other variables, such as neuropsychological test findings, remain controversial. The differential patterns of neuropsychological impairments between Alzheimer and vascular dementia are also questionable. Unlike Alzheimer disease, there is little consensus on the nature and extent of neuropsychological deficits in vascular dementia (Almkvist, Backman, Basur, & Wahlund, 1993; Barr, Benedict, Tune, & Brandt, 1992; Erker, Searight, & Peterson, 1995; Gainotti, Parlato, Monteleone, & Carlomagno, 1992; Libon et al. , 1996; Padovani et al. , 1995; Taylor, Gilleard, & McGuire, 1996; Villiardita, 1993; Wolf, Linn, Babriken, Knoefel, & Albert, 1990). McPherson and Cummings (1996) attributed this to the heterogeneity of vascular dementia, inconsistent diagnostic criteria, and failure to match

groups on key variables. Since patients with these dementias are most likely to be referred for driving evaluations, it is important to understand how these groups perform.

The primary objective of this study is to examine the relationships between groups of individuals diagnosed with Alzheimer disease, vascular dementia, and mixed cognitively impaired older adults on neuropsychological and driving variables. Alzheimer and vascular dementias consist of different disease processes and neuropathology (see McPherson & Cummings, 1996 and Parks, Zec, & Wilson, 1993) . Therefore, it would not be unreasonable to find distinct patterns of cognitive deficits between these illnesses. It is anticipated the vascular dementia group will exhibit a greater degree of deficits than the Alzheimer disease group on executive functioning (Wolf, et al. , 1990; Padovani et al. , 1995; Villiardita, 1993) and motor skills (Almkvist, et al. , 1993) . It is also hypothesized the vascular dementia group will show less impairment than subjects with Alzheimer disease on verbal and visual memory tests (Barr et al. , 1992; Libon et al. , 1996; Padovani et al. , 1995) . No differences in attention, immediate memory, vocabulary, and visual-spatial tasks are expected between the groups (Padovani et al. , 1995) . Fitten et al. (1995) found subjects with mild vascular dementia performed better on driving measures and produced more variability than subjects with early stage Alzheimer disease. Similar results in this study are expected.

Method

Participants

From an existing database, a total of 112 cognitively impaired older adults participated in this study. The sample consisted of 53 participants with Alzheimer disease (32 males, 21 females) , 28 participants with vascular dementia (multi-infarct dementia) (25 males, 3 females) , and 31 participants with mixed cognitive impairments (20 males, 11 females) .

The mixed cognitively impaired group included 4 mixed Alzheimer and vascular dementia, 18 "other cognitive impairments" , and 9 "other medical conditions". The

category of "other cognitive impairments" was comprised of alcoholic dementia, frontal lobe dementia, head injury , neurotoxic exposure, and normal pressure hydrocephalus. Medical conditions also associated with cognitive impairments included diabetes mellitus, depression, Parkinson's disease, and other psychiatric disorders. Many of these conditions are also known to cause cognitive deficits that may also increase crash risk (see Wallace, 1997) .

Participants recruited for this group were referred by physicians to a clinical driving consultation at the Northern Alberta Regional Geriatric Program (NARGP) at the Glenrose Rehabilitation Hospital located in Edmonton, Alberta. All referred patients were asked to participate in the study. The diagnosis of dementia was made by a clinical neuropsychologist or psychologist using Diagnostic and Statistical Manual of Mental Disorders (4th ed.) (DSM-IV) criteria (American Psychiatric Association, 1994) . At the time of the study, all participants were currently driving. Ethical approval for the research study was obtained from the Caritus Health Group, Edmonton General Hospital and University of Alberta, Edmonton, Alberta. Written consent was obtained from all participants, or caregivers where appropriate.

Instruments

Neuropsychological Testing. The neuropsychological tests were administered by psychological assistant under the direction of a neuropsychologist or clinical psychologist. The neuropsychological battery consisted of several tests commonly used in the assessment of dementia (see Parks et al . , 1993; Strauss & Spreen, 1991) and of driving (Ball & Owsley, 1991; Ball, Owsley, Sloane, Roenker, & Bruni, 1993; Hunt et al. , 1993; Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Parasuraman & Nestor, 1991; Rebok, et al. , 1994; Rizzo et al. , 1997) . From this battery, numerous tests were chosen as instruments for this study to assess a wide range of abilities including attention, executive functioning, verbal and visual memory, visual-spatial skills, and motor skills.

For this study, attention was assessed by Trail Making A (TMTA) (Halstead, 1947;

Retain & Wolfson, 1985) and a Orientation task to person, place and time (ORIENT) developed at the Glenrose Rehabilitation Hospital. Trail Making Test B (TMTB) (Halstead, 1947; Retain & Wolfson, 1985) , Stroop Test (STROOP) (Golden, 1978; Stroop, 1935) , and Alternating Movements Test (AMT) (Luria, 1966) were included as measures of executive or "frontal" functioning. Digit Span Forward (DSF) and Backward (DSB) , from Wechsler Memory Scale-Revised (WMS-R) (Wechsler, 1945, 1987) , were included as tests of immediate memory. Immediate, short-term, and long-term verbal memory were evaluated by the California Verbal Learning Test (CVLT) (Delis, Kramer, Kaplan & Ober, 1987) . Continuous Visual Memory Test (CVMT) (Trahan & Larrabee, 1988) and Rey-Osterrieth Complex Figure Test Immediate (30 second) (REY-I) , and Delayed (20 minute) (REY-D) Recall (Osterrieth, 1944; Lezak, 1989; Rey, 1944) were used to assess visual memory. The copy portion of REY (REY-C), Block Design (BLOC) , and Picture Completion (PICT) of the Wechsler Adult-Intelligence Scale-Revised (WAIS-R) (Wechsler, 1945, 1981) , were added as visual-spatial measures. Vocabulary test (VOC) of the WAIS-R was used as a measure of general verbal ability. Motor skills were evaluated by Finger Tapping Test (FTT) (Halstead, 1947; Retain & Wolfson, 1985) . Table 3-1 provides a summary of the neuropsychological tests used in this study. Further description of administration, scoring and psychometric properties of these tests can be obtained in their manuals, as well as from Lezak (1983) and Spreen & Strauss (1991) .

Table 3-1

Description of Neuropsychological Tests

Test	Acronym	Function assessed	References
Orientation Task	ORIENT	attention, orientation to person, place, and time	Glenrose Rehabilitation Hospital, Edmonton, Alberta
Trail Making Test			Halstead (1947) Retain & Wolfson (1985)

Part A	TMTA	visual attention, visual scanning	
Part B	TMTB	executive functioning (visual planning, sequencing)	
Stroop Color & Word Test	STROOP	executive functioning (cognitive flexibility, response shifting)	Golden (1978) Stroop (1935) Spreen & Strauss (1991)
Alternating Hand Movements Test	AMT	executive functioning (motor planning, sequencing)	Luria (1966)
Digit Span			Wechsler Memory Scale-Revised (Wechsler, 1945, 1987)
Forward	DSF	immediate verbal memory	
Backward	DSB	immediate verbal memory, mental control	
Vocabulary	VOC	general verbal ability, semantic memory	Wechsler Adult Intelligence Scale-Revised (WAIS-R) Wechsler (1945, 1981)
California Verbal Learning Test	CVLT	immediate, short-term, long term verbal memory	Delis, Kramer, Kaplan, & Ober (1987)
Continuous Visual Memory Test	CVMT	visual-spatial memory	Trahan & Larrabee (1988)
Rey-Osterrieth Complex Figure Test			Lezak (1988) Osterrieth (1944) Rey (1941)
Copy	REY-C	visual-spatial/constructional abilities	
Immediate Recall	REY-I	visual-spatial short term memory	
Delayed Recall	REY-D	visual-spatial long term memory	
Block Design	BLOC	visual-spatial/constructional abilities	WAIS-R (Wechsler, 1945, 1981)
Picture Completion	PICT	visual-spatial abilities, visual discrimination	WAIS-R (Wechsler, 1945, 1981)
Finger Tapping Test	FTT	fine motor control, manual dexterity	Halstead (1947) Retain & Wolfson (1985)

Driving Measures. Six driving variables from a standardized on-road driving evaluation developed at NARGP were used in this study (see Dobbs, 1997) . These included error scores, Hazard Pass/Fail (HAZ) , Points Pass/Fail (POI) , and driver rating scores, Accident Risk Rating (ACC) , Global Rating (GLOB) , Defensive Driving (DEF) ,

and Driver Skill (DRIV) . These measures are outlined in Table 3-2. Further description of the standardized road test and vehicle are described by Dobbs (1997) . Briefly, the driving test consisted of a 45-minute drive, consisting of 37 standardized maneuvers frequently implicated in crashes of older drivers. The road course consisted of a standardized route including residential, light business and urban freeway. An automatic mid-size, dual brake car was used for the road test. The driving evaluator was a highly experienced certified driving instructor.

Both HAZ and POI are dichotomous variables which result in either pass (0) or failure (1) . HAZ, developed by Dobbs (1997) , has been shown to effectively discriminate between normal and cognitively impaired older drivers. This score included "hazardous" or "potentially catastrophic" driving errors that would likely result in an automobile crash if the evaluator had not taken control or adjusted the traffic conditions. Examples of HAZ would be stopping at a green light or driving the wrong way on a freeway. With regard to scoring, an examinee who made one or more HAZ error was failed. POI, also developed by Dobbs (1997) , is also an empirically-based score, that includes driving errors for which the frequency and severity of those errors discriminates between cognitively impaired and normal drivers. The criterion for failure is norm-based.

The driving examiner also provided driver rating scores on ACC, DEF, and DRIV as well as a composite Global score (GLOB) . ACC scores ranged from one to ten (1 = highest accident risk, 10 = lowest accident risk) . DEF scores ranged from one to five (1 = no difficulties, 2 = minor difficulties, 3 = moderate difficulties, 4 = severe difficulties, 5 = very severe difficulties) . Because DEF scores were ordered in the opposite direction from the other scales, they were reversed for the data analysis to make interpretation less confusing (1 = very severe difficulties, 2 = severe difficulties, 3 = moderate difficulties, 4 = minor difficulties, 5 = no difficulties) . DRIV scores ranged from one to five (1 = very poor, 2 = poor, 3 = average, 4 = above average, 5 = excellent).GLOB scores were derived from the other driver rater scores (less than 11 = unsafe to drive, 11 to 12.5= borderline

pass and 13 or greater = no evidence of safety risk) . Since a factor analysis of these scores had shown all three variables loaded on a single factor (.94 or greater) and this factor accounted for 90.6% of the variance, ACC, DEF, and DRIV were linearly combined to form the GLOB score.

Table 3-2

Description of Driving Performance Measures (Dobbs, 1997)

Measure	Acronym	Description
Hazard Pass/Fail	HAZ	error score, hazardous or potentially catastrophic errors, Pass (0) , Fail (1)
Points Pass/Fail	POI	error score, discriminates among young, old and dementia groups based on number and severity of errors Pass (0) , Fail (1)
Accident Risk	ACC	driver rating score of accident risk (10 point scale: 1 = highest accident risk, 10 = lowest accident risk)
Global	GLOB	driver rating score based on a linear combination of ACC, DEF, and DRIV (less than 11 = unsafe to drive, 11-12.5 = borderline pass, 13 or greater = no evidence of safety risk)
Defensive Driving	DEF	driver rating score of defensive driving (5 point scale: 1 = very severe difficulties, 2 = severe difficulties, 3= moderate difficulties, 4 = minor difficulties, 5 = no difficulties)
Driver Skill	DRIV	driver rating score of driving skill (5 point scale: 1 = very poor, 2 = poor, 3 = average, 4 = above average, 5 = excellent)

Statistical Analyses

Since subjects received different neuropsychological batteries there was considerable missing data across 159 neuropsychological variables in the database ranging from zero to 100% . To address this problem, it was decided a priori, to exclude variables with 10% or more of missing data. As an extra precaution, a listwise deletion procedure in SPSS statistical software (Version 6.1) was used for all statistical analyses. Although a

number of subjects were lost as a result, it was more important to ensure groups remained intact across variables. Making the groups consistent was necessary to accurately compare results across analyses. The original database from which the data was analyzed for this study consisted of 150 cognitively impaired subjects that were classified into five groups: Alzheimer disease, vascular disease, other cognitive impairments, mixed Alzheimer disease and vascular dementia, and other medical conditions. After the listwise deletion procedure, the resulting sample size included 112 cognitively impaired subjects. The groups of mixed Alzheimer disease and vascular dementia, other medical conditions, and other cognitive impairments were combined because of their small numbers.

Prior to the statistical analyses, the data were examined for non-normal distributions, outliers, and errors of coding. The normality of the distributions were visually checked by stem-and-leaf displays. Outliers were also examined by determining the extreme values of each variable. Impossible scores which fell out of the score range for a given test were removed. The remaining extreme values which appeared to be valid were not excluded.

To compare performances of the three groups on neuropsychological and driving measures, a series of one-way analysis of variance (ANOVAs) were performed. Levene's Test of Homogeneity was used to evaluate the assumption of homogeneity of variance for each ANOVA. In cases where homogeneity of variance was violated, the Brown-Forsythe ANOVA modification (F^*) was calculated (Brown and Forsythe, 1974) . To identify which means differed, post hoc Tukey tests for unbalanced designs were conducted (Kramer, 1956; Smith, 1971) . Since this was an exploratory study, an alpha level of .05 was chosen as the level of statistical significance for all analyses except post hoc comparisons. With expected problems of heterogeneous variances, as well as non-normal distributions, a conservative post-hoc test and a stringent alpha level of .01 were chosen to reduce Type I errors (Glass and Hopkins, 1996) .

Results

Demographic Information

As shown in Table 3-3, the Alzheimer disease group had a mean age of 73.16 (SD = 8.62) and a mean educational level of 11.70 (SD = 3.71) years. Age in this group ranged from 46 to 89 years old, 93% were right hand dominant, and 60% were males. The vascular dementia group had a mean age of 73.64 (SD = 7.26) and a mean educational level of 10.25 (SD = 3.49) years. Age in this group ranged from 59 to 92, 100% were right hand dominant, and 89% were males. Mean age of the mixed cognitively impaired group was 71.06 (SD = 11.28) and a mean educational level of 10.39 (SD = 4.71) years. In this group, ages ranged from 43 to 87 years, 65% were males, and 100% were right hand dominant. There were no significant differences between the three groups on either age or education ($p > .05$) . The dementia severity based on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975) on the total sample (N=150) from the original database (N = 150) was 23.57 (SD = 3.69) and the scores ranged from 12 to 30. This rating provides an estimate for the subjects included in this data analysis.

Table 3-3

Demographic Variables of Alzheimer Disease, Vascular Dementia and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)
Age[a]			
M	73.16	73.64	71.06
(SD)	(8.62)	(7.26)	(11.28)
Education[b]			
M	11.70	10.25	10.39

(SD)	(3.71)	(3.49)	(4.71)
Gender (% Male)	60%	89%	65%
Handedness (% Right)	93%	100%	100%

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease), VAS = Vascular Dementia, MIX = Mixed Cognitively Impaired.

[a]F= (2, 109) = .72 , p >.05, [b]F (2, 109) = 1.70 , p > .05.

Analysis of Variance

Results of the Levene test revealed the assumption of homogeneity of variance was violated at the .05 significance level for almost all neuropsychological measures. As a result, the Brown-Forsythe correction (F*) was performed on all ANOVAs. In the vast majority, the corrected F* made no difference regarding significance of group effects, as compared to uncorrected F-values. In cases where F* and uncorrected F both produced significant results at .05 significance level, uncorrected F-values are reported. In these instances, the corrected F* produced no significant mean differences, whereas the uncorrected F did. Since F* is a truer and less biased reflection of significant mean differences when homogeneity of variance is violated, corrected F* values are reported for those scores at the .05 significance level.

The accompanying tables present mean raw neuropsychological and driving test scores, standard deviations, F-values (df = 2, 109) , and post hoc differences for the Alzheimer disease group (DAT) , vascular dementia group (VAS) , and mixed cognitively impaired older adults group (MIX) . One way ANOVA's revealed significant group differences for many neuropsychological and driving variables ($p < .05$ to $p < .001$), with the MIX group exhibiting the overall least amount level of impairment on both neuropsychological and driving measures.

Attention. Table 3-4 provides a summary of the attention measures. On ORIENT, a measure of attention and orientation to place, person, and time, significant group

differences were observed, $F = 10.69$, $p < .005$. DAT was significantly more impaired than the MIX group. Although DAT performed slightly poorer than VAS, this difference was not significant. No group differences were found on TMTA performance, $F^* = 3.61$, $p > .05$, and there was considerable variability within each group.

Table 3-4

Attention in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Orientation Task					
M	15.83	17.79	18.94	10.69**	DAT<MIX
(SD)	(3.64)	(2.54)	(2.37)		
Trails Making Test A					
M	77.19	83.64	54.58	3.61[a]	DAT,VAS,MIX
(SD)	(65.57)	(43.51)	(20.47)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

DAT<MIX = significant differences ($p < .01$) between DAT and MIX.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Executive Functioning. Table 3-5 presents a summary of the executive functioning measures. On the STROOP, significant group differences were obtained for word, $F =$

6.29, $p < .005$, color, $F = 3.92$, $p < .05$, and color-word, $F = 5.42$, $p < .005$. VAS performed significantly poorer on the word score than the MIX group, whereas DAT obtained a significantly lower score from MIX group on the color-word score. VAS performed significantly poorer than the DAT group on word score. On TMTB, ANOVA results indicated group differences, $F = 4.30$, $p < .05$, however these differences failed to reach the .01 significance level using Tukey post-hoc comparisons. With regard to AMT, no significant differences ($p > .05$) were found on clench/extend, $F = .49$, tapping, $F = 1.35$, and total, $F = 2.09$, scores. The only significant difference was identified on palm up/palm down score, $F = 6.14$, $p < .005$. On this sub-test, VAS performed significantly poorer than MIX. On this score, DAT and VAS obtained similar scores and were not significantly different.

Table 3-5

Executive Functioning in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT ($n = 53$)	VAS ($n = 28$)	MIX ($n = 31$)	F value ($df = 2, 109$)	Group differences
Stroop Color & Word Test					
Word					
(M)	79.34	60.64	77.74	6.29**	VAS<DAT
(SD)	(25.05)	(19.82)	(23.68)		
Color					
M	60.87	58.32	73.06	3.92*	VAS<MIX
(SD)	(24.74)	(19.07)	(21.03)		
Color-word					
M	26.36	27.46	33.81	5.42**	DAT<MIX

(SD)	(10.11)	(9.78)	(10.93)		
Trails Making Test B					
M	232.42	248.57	189.48	4.30*	DAT, VAS, MIX
(SD)	(79.25)	(76.66)	(90.30)		
Alternating Movements Test					
Palm up/palm down					
M	1.26	.89	1.65	6.14**	VAS<MIX
(SD)	(.81)	(.99)	(.66)		
Clench/extend					
M	.53	.61	.71	.49	DAT, VAS, MIX
(SD)	(.80)	(.83)	(.82)		
Tapping					
M	1.26	1.54	1.51	1.35	DAT, VAS, MIX
(SD)	(.90)	(.79)	(.77)		
Total					
M	3.05	3.04	3.87	2.09	DAT, VAS, MIX
(SD)	(1.97)	(1.97)	(1.72)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

VAS<MIX = significant differences ($p < .01$) between VAS and MIX.

DAT<MIX = significant differences ($p < .01$) between DAT and MIX.

VAS<DAT = significant differences ($p < .01$) between VAS and DAT

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

=Brown-Forsythe corrected F reported.

* p < .05, ** p < .005, *** p <.001, two-tailed.

General Verbal Ability. The results of VOC, a measure of general verbal ability, is provided in Table 3-6. Significant group differences were detected, F = 5.21, p <.05. The VAS group obtained a significantly lower score than the MIX group and no significant differences between VAS and DAT were observed.

Table 3-6

Vocabulary (WAIS-R) performance in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
M	34.60	31.21	42.19	5.21*	VAS<MIX
(SD)	(13.70)	(12.39)	(14.50)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

VAS<MIX = significant differences (p < .01) between VAS and MIX.

* p < .05, two-tailed.

Immediate Memory. Table 3-7 provides a summary of test results of immediate memory. No significant group differences (p>.05) were obtained on DSF, F=2.14, or DSB, F=2.63.

Table 3-7

Immediate Memory in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Digit Span-Forward					
M	6.57	6.82	7.48	2.14	DAT,VAS,MIX
(SD)	(1.90)	(1.98)	(2.08)		
Digit Span-Backward					
M	4.40	4.32	5.29	2.63	DAT,VAS,MIX
(SD)	(1.94)	(1.70)	(2.00)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Verbal Memory. Table 3-8 presents the results of verbal memory performance as measured by the CVLT. Significant group difference were observed in many scores from the CVLT including immediate recall list 5, $F = 15.03$, $p < .001$, lists 1-5 total, $F = 12.84$, $p < .001$, short delay cued recall, $F = 9.48$, $p < .005$, and long delay cued recall, $F = 13.52$, $p < .001$. DAT recalled significantly fewer words on immediate recall list 5, list 1-5 total recall, short delay, and long delay cued recall than the MIX group. DAT and MIX performed at a similar level on these measures and were not statistically different. No significant differences ($p > .05$) were detected for immediate recall list 1, $F = 5.56$, short

delay free recall, F* = 10.56, long delay free recall, F* = 12.79, cued recall intrusions, F* = 7.83, and free recall intrusions, F = .80.

Table 3-8

California Verbal Learning Test Performance in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Immediate recall list 1					
M	2.47	2.93	3.81	5.56*	DAT,VAS,MIX
(SD)	(1.72)	(1.68)	(1.94)		
Immediate recall list 5					
M	4.19	5.57	7.26	15.03***	DAT<MIX
(SD)	(2.03)	(2.85)	(2.83)		
Lists 1-5 - total recall					
M	18.36	23.18	29.52	12.84***	DAT<MIX
(SD)	(8.74)	(9.90)	(11.20)		
Short delay free recall					
M	1.47	3.36	4.29	10.56[a]	DAT,VAS,MIX
(SD)	(1.78)	(3.05)	(3.09)		
Short delay cued recall					
M	3.66	4.82	6.29	9.48**	DAT<MIX
(SD)	(2.15)	(3.29)	(2.89)		
Long delay free recall					
M	1.42	3.50	4.71	12.79[a]	DAT,VAS,MIX

(SD)	(1.78)	(3.36)	(3.07)		
Long delay cued recall					
M	3.19	4.89	6.29	13.52***	DAT<MIX
(SD)	(2.30)	(3.29)	(2.70)		
Cued recall intrusions					
M	10.58	5.50	5.12	7.83[a]	DAT,VAS,MIX
(SD)	(8.84)	(5.22)	(4.57)		
Free recall intrusions					
M	6.42	4.96	5.13	.80	DAT,VAS,MIX
(SD)	(6.53)	(4.96)	(4.98)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

VAS<MIX = significant differences ($p < .01$) between VAS and MIX.

DAT<MIX = significant differences ($p < .01$) between DAT and MIX.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Visual Memory. Results of visual memory performance are presented in Table 3-9. On the CVMT, significant group differences were observed on only total score ($F=4.91$, $p<.05$) . Total score, is a composite score of number of hits added with number of correct recognitions. On this test, the DAT group performed poorer than the MIX group, and similar to the VAS group. With regard to the other three scores included in the analysis, smaller significant group differences were identified for false alarms, $F = 3.60$, $p < .05$, and d-prime, $F = 3.74$, $p < .05$. Post hoc analysis at the .01 significance level failed to reveal any group differences on these measures. No significant differences were observed

on hits score, $F = 2.62$, $p > .05$.

On REY-I and REY-D, two other measures of visual-spatial memory, significant group differences were obtained ($F = 4.75$, $p < .05$, $F = 5.83$, $p > .005$, respectively) . However, no differences were found on the REY-I in post hoc comparisons. On REY-D, the DAT group performed at a comparable level with the VAS group, and poorer than the MIX group.

Table 3-9

Visual Memory in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Continuous Visual Memory Test					
Hits					
M	34.08	30.71	34.71	2.62	DAT,VAS,MIX
(SD)	(6.65)	(8.95)	(6.67)		
False alarms					
M	27.94	23.78	24.54	3.60*	DAT,VAS,MIX
(SD)	(8.49)	(7.41)	(9.18)		
D-prime					
M	1.00	.86	1.32	3.74*	DAT,VAS,MIX
(SD)	(.74)	(.78)	(.49)		
Total					
M	60.13	60.93	65.65	4.91*	DAT<MIX
(SD)	(9.04)	(7.29)	(6.51)		

Rey Osterrieth Complex Figure Recall Test					
Immediate recall					
M	11.26	17.25	18.64	4.75*	DAT,VAS,MIX
(SD)	(11.16)	(11.51)	(12.57)		
Delayed recall					
M	8.34	14.54	17.06	5.83**	DAT<MIX
(SD)	(11.09)	(12.26)	(13.18)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

VAS<MIX = significant differences ($p < .01$) between VAS and MIX.

DAT<MIX = significant differences ($p < .01$) between DAT and MIX.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Visual-Spatial Skills. Table 3-10 provides a summary of visual-spatial performance. On REY-C, no significant differences were detected between the three groups, $F^* = 3.36$, $p > .05$. Although significant group differences were obtained on BLOC, $F = 5.12$, $p < .05$, post-hoc tests failed to identify any differences at the .01 level. On PICT, significant differences were obtained, $F = 6.35$, $p < .005$. The DAT group did show more impairment on this task than the MIX group, but obtained similar scores to the VAS group.

Table 3-10

Visual-Spatial Skills in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Rey-Osterrieth Complex Figure Copy Test					
M	52.66	53.89	60.13	3.36[a]	DAT,VAS,MIX
(SD)	(14.57)	(14.54)	(9.20)		
Block Design					
M	11.74	10.86	17.52	5.12*	DAT,VAS,MIX
(SD)	(9.98)	(7.47)	(8.76)		
Picture Completion					
M	7.57	8.86	11.13	6.35**	DAT<MIX
(SD)	(4.53)	(4.16)	(4.48)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

DAT<MIX = significant differences ($p < .01$) between DAT and MIX.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Motor Skills. Results of the FTT, a measure of fine motor skills are provided in Table 3-11. Significant differences in performance with the dominant hand, $F = 6.42$, $p < .005$, and non-dominant hand, $F = 5.02$, $p < .05$, were obtained. For the dominant hand, VAS performed significantly poorer than the DAT group. Mean score differences with the

non-dominant hand failed to be significantly different at the .01 level of significance using Tukey.

Table 3-11

Finger Tapping Test Performance in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT (n = 53)	VAS (n = 28)	MIX (n = 31)	F value (df = 2, 109)	Group differences
Dominant Hand					
M	42.08	34.90	42.44	6.42**	VAS<DAT
(SD)	(9.40)	(9.43)	(9.23)		
Non-dominant hand					
M	38.15	32.14	37.68	5.02*	DAT, VAS,MIX
(SD)	(8.78)	(8.42)	(7.98)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

VAS<DAT = significant differences ($p < .01$) between VAS and DAT.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

'=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Driving Performance. Table 3-12 provides the results of driving performance. Seventy percent of the DAT group, 64% of the VAS group, and 42% of the MIX group received a HAZ error. For GLOB scores, 32 (60%) subjects of the DAT group, scored under 11 (unsafe to drive), 13 (25%) scored in the 11 to 12 range, and 8 (15%) scored in the 13 or greater range (no driving risk) : Twenty-one (75%) subjects in the VAS group

obtained a score less than 11, four (14%) received a score in the 11 to 12 range, and three (11%) scored 13 or more. In the MIX group, 13 (42%) scored under 11, 6 (19%) scored in the 11 to 12 range, and 12 (39%) scored in the 13 or greater range.

Significant differences were found for ACC, $F = 5.61$, $p < .005$, GLOB, $F = 5.06$, $p < .05$, DEF, $F = 3.73$, $p < .05$, and DRIV, $F = 3.20$, $p < .05$. Post hoc analyses identified that the VAS group performed poorer on ACC, GLOB, and DRIV compared to the MIX group. On these measures DAT and VAS performed at a comparable level. None of the groups were significantly different on DRIV ($p < .01$) .

Table 3-12

Driving Performance in Alzheimer Disease, Vascular Dementia, and Mixed Cognitive Impairment Groups

Variable	DAT ($n = 53$)	VAS ($n = 28$)	MIX ($n = 31$)	F value ($df = 2, 109$)	Group differences
Hazard Points Pass/Fail					
M	.70	.64	.42	----	----
(SD)	(.46)	(.49)	(.50)		
Points Pass/Fail					
M	.23	.43	.26	----	----
(SD)	(.42)	(.50)	(.44)		
Accident Risk					
M	4.25	3.75	5.18	5.61**	VAS<MIX
(SD)	(1.62)	(1.85)	(1.62)		
Global Rating					
M	9.47	8.48	11.05	8.06*	VAS<MIX

(SD)	(3.28)	(3.23)	(2.85)		
Defensive Driving					
M	2.98	2.71	3.35	3.73*	DAT, VAS, MIX
(SD)	(1.01)	(.80)	(.81)		
Driver Skill					
M	2.25	2.01	2.52	3.20*	DAT, VAS, MIX
(SD)	(.80)	(.76)	(.68)		

Note. DAT = Dementia of the Alzheimer Type (Alzheimer disease) Group, VAS = Vascular Dementia Group, MIX = Mixed Cognitively-Impaired Group.

---- = ANOVA not calculated as HAZ and POI were dichotomous variables.

VAS<MIX = significant differences ($p < .01$) between VAS and MIX.

DAT,VAS,MIX = no significant differences ($p > .01$) between groups.

[a]=Brown-Forsythe corrected F* reported.

* $p < .05$, ** $p < .005$, *** $p < .001$, two-tailed.

Discussion

This study compared several neuropsychological test and driving scores for three groups: (a) Alzheimer disease (b) vascular dementia; and (c) a group of mixed cognitively impaired older adults. It was anticipated the VAS group would exhibit a greater degree impairment than the DAT group on executive functioning (Padovani et al. , 1995; Wolf, et al. , 1990; Villiardita, 1993) and motor skills (Almkvist, et al. , 1993) . It was also hypothesized the VAS group would show less impairment on verbal and visual memory tasks (Barr et al., 1992; Libon et al. , 1996; Padovani et al. , 1995) . No differences in attention, immediate memory, vocabulary or visual-spatial were expected between the two dementias (Padovani et al. , 1995) . Fitten et al. (1995) found that early vascular dementia subjects performed better on driving measures and produced more variability than subjects

with mild Alzheimer disease. It was expected that similar results would be obtained in this study. The purpose of exploring group difference across a large number of neuropsychological and driving variables was to provide clinicians with quantitative data for specific groups of cognitive impairment.

One-Way ANOVAs and Description of Neuropsychological Tests. On the vast majority of tests, the DAT and VAS groups did not perform significantly different. The patterns of performance across the groups are described below.

DAT<MIX. The DAT group was significantly more impaired than the MIX group on ORIENT, color-word score of the STROOP, four scores on the CVLT (immediate recall List 5, lists total 1-5, short and long delay cued recall) , total score of the CVMT, REY-I, REY-D, and PICT. These findings suggested the DAT group exhibited a greater degree of short-term and long-term visual and verbal memory deficits than a mixed group of cognitively impaired older adults. It is not surprising these results were obtained, as deficits in verbal episodic memory are one the distinguishing features of Alzheimer disease (Cullums, Filley, & Kozora, 1995; Desgranges, Eustache, Rioux, de la Sayette, & Le chevalier, 1996; Parks, et al. , 1993) . On these scores, the differences between VAS and MIX did not reach statistical significance.

VAS<MIX.The VAS group performed significantly poorer than the MIX group on color score of the STROOP test, palm up/palm down of the AMT, and VOC. On these measures, the DAT and MIX scores were not significantly different. Other studies have reported that VAS groups perform poorer on similar executive functioning tasks compared to healthy older adult control groups (Padovani et al. , 1995; Wolf et al. , Villiardita, 1993) .

DAT, VAS, MIX. However, on a majority of neuropsychological tests, no significant differences between groups were identified. They included TMTA, TMTB, AMT, (clench/extend, tapping, total scores), DSF, DSB, several scores on the CVLT (immediate recall list 1, short and long delay free recall, cued and free recall intrusions

scores, hits, false alarm and d-prime of the CVMT, REY-C, REY-I, non-dominant hand of the FTT, and BLOC. These results indicate that many neuropsychological tests are unable to differentiate dementia groups from a heterogeneous cognitively impaired older adult group.

Many of the hypotheses pertaining to the expected differences between DAT and VAS were supported in this finding. The failure to find significant differences between DAT and VAS on measures of attention (ORIENT, TMTA), immediate memory (DSF, DSB) , vocabulary, and visual-spatial tasks (BLOC, REY-C, PICT) , confirm the findings of Padovani et al. (1995) . They concluded that these particular neuropsychological domains cannot differentiate between these dementias.

With regard to executive functioning, inconsistent results were obtained in this study. The only measure to differentiate DAT and VAS was the word score of the STROOP. Performances on TMTB, AMT, and the other STROOP scores were not significantly different. Previous studies have suggested that vascular dementia subjects score lower on executive functioning or "frontal lobe" tasks. Padovani et al. (1995) reported that their VAS sample exhibited a greater number of perservative errors on the Wisconsin Card Sorting Test and produced fewer words on the Controlled Oral Word Association Test. However, they did report that the STROOP could not differentiate between VAS and DAT.

Contrary to prior research (Delis et al. , Libon et al. , 1996; Padovani et al. , 1995) , this study failed to find significant differences between DAT and VAS on visual and verbal memory tasks. The CVLT, CVMT, REY-I, and REY-D all failed to differentiate DAT and VAS groups. Unlike this study, Padovani et al. (1995) , reported that their sample of DAT exhibited a greater level of impairment than VAS subjects on the CVLT and visual memory tasks such as the Corsi Cube Test. However, it was interesting to note that similar to Libon et al. (1996) , this study found that DAT groups produced a higher number of intrusion errors on the CVLT than the VAS group. In this study these differences did not

reach statistical significance. These contradictory findings could possibly be explained by differences in samples and methodology. For example, this study used a .01 alpha level for post-hoc comparisons, whereas Padovani et al. (1995) used a .05 alpha level.

Almkvist et al. (1993) has also found that motor skills tend to be more impaired in subjects with VAS compared to DAT. Using the FTT, similar results were also obtained for the dominant hand of the FTT. On this score, the VAS group obtained significantly lower scores than the DAT group.

One-Way ANOVAs and Description of Driving Performance. Driving measures were obtained from a standardized on-road driving evaluation which included error scores of HAZ and POI and driver rating scores of ACC, DEF, DRIV, and GLOB. Seventy percent of the DAT group, 64% of the VAS group, and 42% of the MIX group received a HAZ error. For GLOB scores, 60% subjects of the DAT group, scored in the unsafe range, 25% scored in the borderline pass range, and 15% scored in the no driving risk range. Seventy-five percent subjects in the VAS group obtained a score in the unsafe range, 14% received a score in the borderline pass range, and 11% scored in the no driving risk range. In the MIX group, 42% scored in the unsafe range, 19% scored in the borderline range and 39% scored in the no driving risk range. Based on these frequency distributions, no clear differential patterns between DAT and VAS. However, when comparing these diagnostic groups to the MIX group, the MIX group obtained a lower percentage subjects who received a HAZ error, and a higher percentage who obtained GLOB scores in the no driving risk range.

Contrary to the report by Fitten et al. (1995) , using ANOVAs, the DAT group did not perform significantly worse than the VAS group on any driving measure. Nor did the VAS group exhibit greater variability on driving. The VAS group performed poorer than the MIX group on ACC, DRIV, and GLOB. However, on these measures VAS and DAT groups were not significantly different.

Consistent with previous reports, these findings indicate that driving impairment is

common in cognitively impaired older adults (Ball et al. , 1993; Fitten et al. , 1997; Hunt et al. , 1993; Rebok et al. , 1994; Rizzo et al. , 1997) . Confirming other studies (Dobbs, 1997; Friedland et al. , 1988; Hunt et al. , 1993: Rizzo et al. , 1997) , a minority of subjects within each group seemed to exhibit no driving hazard. A diagnosis of either Alzheimer or vascular dementia did not discriminate driving ability.

Homogeneity of Variance. The assumption of homogeneity of variance needed for ANOVA was violated for many neuropsychological tests. This required additional statistical corrections to interpret the results accurately. Very high standard deviations occurred in many neuropsychological variables in all groups. Examples of rather high standard deviations in the DAT group included TMTA (SD = 65.57) , color score of the STROOP (SD = 24.74) , and REY-C (SD = 14.57) . In the VAS group, the standard deviations for these tests were respectively, 43.51, 19.07, and 14.54. With regard to the MIX group, the respective standard deviations for these tests were 20.47, 21.03 and 9.20.

Hunt et al. (1993) also reported a high standard deviation for TMTA (SD = 23.8) in their sample of older adults, as did Padovani et al. (1995) for the REY in patients with Alzheimer disease (SD = 24.8) . Other studies have also reported large variability in neuropsychological test scores in patients with Alzheimer disease (Desgranges et al. , 1996; Hanninen et al. , 1997; Malec et al. , 1993; Mitrushina, Uchiyama, & Satz, 1995) and even larger standard deviations in patients with vascular dementia (McPherson & Cummings, 1996) .

Interestingly, the behavioral driving measures produced much smaller standard deviations and did not violate the homogeneity of variance assumption. For example, the standard deviations for the GLOB score were very low (DAT, SD = 3.28, VAS, SD = 3.23, MIX, SD = 2.85) . Moore and Litchenberg (1996) , Wallace (1997) and Milberg (1996) , have criticized neuropsychological tests for their inability reflect everyday functional behavior in older adults.

Advantages and Limitations. This study offered numerous methodological and

substantive improvements over previous research. The validated road test variables provided a strong base from which to compare the various neuropsychological instruments. Only a few studies (Dobbs, 1997; Fitten et al. , 1995; Hunt et al. , 1993) have also evaluated driving abilities using a standardized road-test. A statistical correction was used to address the violation of homogeneity of variance which occurred in many neuropsychological variables. Furthermore, to address the expected problems of heterogeneous variances and non-normal distributions, a .01 alpha level was chosen for post hoc comparisons. Precautions were also taken to ensure subjects remained consistent across variables in order to make accurate group comparisons.

To date, this was the first driving study to compare VAS and DAT with such a large sample size that were comparable on age and education. The study by Fitten et al. (1995) included 15 patients with mild Alzheimer disease, 12 patients with vascular dementia (multi-infarct dementia) , 15 patients with diabetes, and 26 healthy older adults. Their groups were all matched for age, and for neuropsychological tests included the Mini Mental State Examination and the Clock Drawing Test. This study incorporated a broad range of commonly used neuropsychological tests. It also included many neuropsychological tests that have not been previously associated with driving performance. These were the CVLT, CVMT, AMT, VOC, DSF, DSB, PICT, and FTT. With regard to the VAS group, it may have been helpful to have information regarding the location and number of cerebral lesions, especially for conducting group comparisons with ANOVA (McPherson & Cummings, 1996) .

Recommendations for Future Research. Emerging from this study were a number of recommendations for future research to consider. Replication of this study with similar variables with a comparable sample would add confidence to the conclusions drawn in this study with regard to the relationship between neuropsychological test scores and driving performance. As a precaution proceeding research using ANOVA should always check the assumption of homogeneity of variance. Dobbs, (1997) , Fitten et al. (1995) , Rebok et al.

(1994) , and Rizzo et al. (1997) , have advocated the development of empirically based driving evaluations which include cognitive screening tools that predict driving risk. The neuropsychological instruments reviewed in this study would not appear to make strong contributions towards this goal. Wallace (1997) supports this conclusion.

Conclusion. Seventy-five percent of the VAS group, 60% of the DAT group, and only 39% of the MIX group made a hazardous or potentially catastrophic driving error during the road test. The differences between DAT and VAS on the other driving measures were small and insignificant. Furthermore, most neuropsychological variables failed to find group differences between DAT and VAS. Since Alzheimer and vascular dementias are implicated with increased crash risk (Ball et al. , 1993; Fitten et al. , 1997; Hunt et al. , 1993; Rebok et al. , 1994; Rizzo et al. , 1997) , additional research is recommended.

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CHAPTER 4

SUMMARY

The purpose of this thesis was to examine the relationships between several neuropsychological test scores and performance-based driving measures in cognitively impaired older adults. A documentation of the relationships between neuropsychological test scores and driving ability will be very useful for clinicians who are placed in a position of having to provide driving recommendations. With further research, neuropsychological variables that predict driving could be developed into a quick and cost-effective screening tool to indicate driving risk. The following sections include a summary of the hypotheses from Paper I and II, limitations and delimitations of this thesis, suggestions for future research, and concluding remarks.

Summary of Hypotheses

Paper I

Hypothesis 1. It was expected that the CIG group would exhibit a greater level of impairment on neuropsychological and driving measures than control groups. Results from one-way ANOVAs revealed CIG had poorer scores across all neuropsychological domains compared to the control groups. These included measures of attention (ORIENT, TMTA) , executive functioning (STROOP, TMTB, AMT) , general verbal ability (VOC) , immediate memory (DSF, DSB) , verbal memory (CVLT) , visual memory (CVMT, REY-I, REY-D) , visual-spatial skills (BLOC, PICT, REY-C) , and motor skills (FTT) .

Post hoc comparisons determined that many neuropsychological tests differentiated between all groups, with the CIG performing the worst, and YCG, the best. These measures included one measure of attention (TMTA) , two tests of executive functioning (TMTB, clench/extend and total scores of the AMT) , and two tests of visual memory (false alarm and total score of the CVMT, REY-I, REY-D) . On the CVLT, significant differences were obtained between all groups on all measures except free and cued intrusion recall

errors. Another test to produce significant differences between all groups was BLOC, a measure of visual-spatial/visual-constructional ability.

On other neuropsychological tests, the CIG faired much worse than both control groups who performed at a comparable level. No differences were identified between control groups on ORIENT, all scores of the STROOP, palm up/palm down score of AMT, VOC, DSF, DSB, cued and free intrusion recall errors of CVLT, d-prime and hits scores of the CVMT, REY-C, PICT, and FTT.

Driving measures were obtained from a standardized on-road driving evaluation which included error scores of HAZ and POI, and driver rating scores of ACC, DEF, DRIV, and GLOB. The most notable finding was that none of the control group subjects made a HAZ error, whereas 61% of the CIG made this type of error. This suggests that cognitively impaired older adults are more likely to make serious and dangerous driving errors. Sixty-six subjects in the CIG obtained a GLOB score in the "unsafe driving" range, 23 fell in the borderline pass range, and 23 fell in the pass range. Only three subjects in the OCG fell in the unsafe range and none of the YCG did. Post hoc comparisons identified significant differences between all groups on ACC and GLOB. However, on measures of DEF and DRIV, the control groups performed at a comparable level. It appeared that older healthy older drivers and even a minority with cognitive impairment posed little driving risk.

Hypothesis 2. It was also hypothesized that visual-spatial, attention and executive functioning will be strongly related to driving performance. In the total sample (N = 192) , the largest correlations above .60 were between TMTA, TMTB, REY-C, REY-I, REY-D, BLOC, and PICT with GLOB. These neuropsychological measures were also strongly correlated with DEF, DRIV, and ACC. POI and HAZ scores produced lower correlations with all of the neuropsychological scores.

In the CIG, TMTA, TMTB, REY-C, and BLOC were strongly correlated above .50

with GLOB and ACC scores. These highly related neuropsychological tests all required visual attention, visual-spatial, and executive planning skills. Smaller correlations were also obtained between neuropsychological tests with HAZ and POI.

Overall, weak correlations were produced in the OCG between neuropsychological test scores and driving measures. Very few correlations reached statistical significance. The highest correlations with GLOB included color-word score of the STROOP, REY-C, dominant hand of the FTT, and BLOC. However, none of the correlations were above .50. With regard to the YCG, even lower correlations were produced between neuropsychological test scores and driving variables. The vast majority of correlations were less than .20 and none were above .50.

This study ascertained patterns of highly correlated neuropsychological and driving variables and built two regression models based on those findings. In the CIG, the neuropsychological tests that most highly correlated with GLOB were TMTA, TMTB, REY-C, BLOC, and PICT. The resulting multiple regression model using those five visual-spatial measures accounted for almost 40% of the variance in the GLOB score. Of all the independent variables included in this regression model, TMTA, TMTB, and REY-C were the strongest predictors of the GLOB score.

In the OCG, the five neuropsychological variables that were most highly correlated with GLOB were TMTB, color-word score of the STROOP, REY-C, BLOC, and FTT. These variables accounted for approximately 33% of the variance in the GLOB score. The REY-C and dominant hand score of the FTT were the strongest predictors of GLOB .

Paper II

<u>Hypothesis 1.</u> It was expected that DAT and VAS would exhibit a differential pattern of neuropsychological impairment. Specifically, it was anticipated the VAS group would exhibit a greater degree of executive functioning and motor deficits than the DAT group. It was also hypothesized the VAS group would show less impairment than the DAT group on verbal and visual memory. No differences in

attention, immediate memory, visual-spatial, and vocabulary scores were expected.

On the vast majority of neuropsychological tests, there were no significant differences between VAS and DAT. Specifically, no significant differences were found between DAT and VAS on measures of attention (ORIENT, TMTA) , immediate memory (DSF, DSB) , vocabulary, and visual-spatial tasks (BLOC, REY-C, PICT) . Overall, it appeared that these particular neuropsychological domains could not differentiate between these dementias.

With regard to executive functioning, inconsistent results were obtained in this study. The only measure to differentiate DAT and VAS was the word score of the STROOP. Performances on TMTB, AMT, and the other STROOP scores were not significantly different. This study failed to find significant differences between DAT and VAS on visual and verbal memory tasks. The CVLT, CVMT, REY-I, and REY-D all failed to differentiate DAT and VAS groups. Using the FTT, similar results were also obtained for the dominant hand of the FTT. The VAS group obtained significantly lower scores than the DAT group.

Hypothesis 2: It was expected that the DAT group would perform better than the VAS group and exhibit less variability on the driving measures. Seventy percent of the DAT group, 64% of the VAS group, and 42% of the MIX group received a HAZ error. For GLOB scores, 60% subjects of the DAT group, scored in the unsafe range, 25% scored in the borderline pass range, and 15% scored in the no driving risk range. Seventy-five percent subjects in the VAS group obtained a score in the unsafe range, 14% received a score in the borderline pass range, and 11% scored in the no driving risk range. In the MIX group, 42% scored in the unsafe range, 19% scored in the borderline range and 39% scored in the no driving risk range. Based on these frequency distributions, no clear differential patterns between DAT and VAS emerged. However when comparing these diagnostic groups to the MIX group, the MIX group obtained a lower percentage of subjects who received a HAZ error and a higher percentage of subjects

who obtained GLOB scores in the no driving risk range.

Using ANOVAs, the DAT group did not perform significantly worse than the VAS group on any driving measure. Nor did the VAS group exhibit greater variability on driving. The VAS group performed poorer than the MIX group on ACC, DRIV, and GLOB. No significant differences were found on DEF. These findings indicate that driving impairment is common in cognitively impaired older adults with a dementia, yet a minority of subjects within both dementia groups seemed to exhibit little driving hazard.

Delimitations and Limitations

This thesis offered numerous methodological and substantive strengths. The validated road test variables provided a strong base to compare neuropsychological instruments. A statistical correction was used to address the violation of homogeneity of variance which occurred in many neuropsychological variables. Due to unequal subject numbers per group, non-normal distributions, and heterogeneity of variances, a stringent alpha level of .01 for post-hoc comparisons minimized the risk of Type I errors. Precautions were also taken to ensure subjects remained consistent across variables in order to make accurate group comparisons. Additionally, both papers had a substantial sample size. To date, no other study has compared Alzheimer and vascular dementia with such a large sample. This study incorporated a broad range of commonly used neuropsychological tests. It also included many neuropsychological tests that have not been previously associated with driving performance. These were the CVLT, CVMT, REY-I, REY-D, AMT, VOC, DSF, DSB, PICT, and FTT.

A shortcoming of both papers pertained to group composition. In Paper I, it may have been helpful to include a higher number of males in the YCG and a higher number of females in the OCG. Increasing gender representation in these groups would have provided a more inclusive database. This is important when using ANOVA, as gender is a demographic factor known to affect neuropsychological test scores. With regard to Paper II, it may have been useful to have information regarding the location and number of

cerebral lesions in the VAS group, particularly for comparing neuropsychological test results (McPherson & Cummings, 1996) .

Recommendations for Future Research

Emerging from this study were a number of recommendations for future research to consider. Replication of this study with similar variables with a comparable sample would add confidence to the conclusions drawn in this study with regard to the relationship between neuropsychological test scores and driving performance. Since Alzheimer and vascular dementias are implicated in increased crash risk, additional research examining these particular groups is recommended. As a precaution proceeding research using ANOVA should always check the assumption of homogeneity of variance. Dobbs, (1997) , Fitten et al. (1995) , Rebok et al. (1994) , and Rizzo et al. (1997) , have advocated the development of empirically based driving evaluations which include cognitive screening tools that predict driving risk. Before neuropsychological screening protocols for driving competency can be developed, research may need to address the fundamental issues of reliability and validity in geriatric neuropsychological assessments (see Milberg, 1996; Wallace, 1997) .

Concluding Remarks

Most common in older adults, progressive dementia is a serious public health problem with significant ramifications, in terms of health care costs, and its devastating impact on patients and families. The older adult population over 65 years old, is the fastest growing age group in our society and age-related dementias are significantly rising. One important issue pertaining to this population is driving competency. Increased crash risk is associated with advancing age, most likely caused by illnesses such as dementia, which affect cognitive functioning.

This study confirmed that a significant portion of older adults with dementia and other cognitive impairments pose a driving hazard. On the other hand, these findings indicate that healthy older adults and even a small proportion of older adults with cognitive

impairments or dementia pose little driving risk. The differences between Alzheimer and vascular dementias on neuropsychological and driving measures were small and most failed to reach statistical significance. Although visual-spatial and higher-order cognitive abilities of planning and sequencing appeared to be highly associated with driving performance, it would be premature to rely on neuropsychological test findings to make decisions regarding driving competency. In terms of public safety, all older adults with suspected cognitive impairment could be referred for a standardized performance-based driving evaluation.

APPENDIX

CORRELATIONS OF DRIVING PERFORMANCE

This appendix contains the separate correlation analyses from paper I for the total sample, the CIG, OCG, and YCG.

Total Sample

Table A-1 presents correlations between neuropsychological and driving measures for the 192 subjects in the sample.

Attention. On measures of attention, TMTA strongly correlated ($p < .001$) with GLOB, $r = -.63$, ACC, $r = -.62$, DEF, $r = -.60$, and DRIV, $r = -.57$. A weak but still significant correlation was obtained for TMTA and HAZ, $r_{pb} = .24$, $p < .01$. ORIENT was strongly correlated ($p < .001$) with GLOB, $r = .55$, and moderately correlated ($p < .001$) with DRIV, $r = .48$, HAZ, $r_{pb} = -.45$, and DEF, $r = .48$. Both TMTA and ORIENT were weakly correlated with POI, $r_{pb} = .18$, $p < .05$, $r_{pb} = -.22$, $p < .01$, respectively.

Executive Functioning. With regard to executive functioning, TMTB strongly correlated ($p < .001$) with ACC, $r = -.73$, GLOB, $r = -.72$, DRIV, $r = -.68$, DEF $r = -.61$, and HAZ, $r = .53$. TMTB moderately correlated ($p < .001$) with POI, $r_{pb} = .34$.

For STROOP scores, overall smaller, but still strong correlations ($p < .001$) were observed between color word and ACC, $r = .51$, and GLOB, $r = .51$. Color word score moderately correlated ($p < .001$) with DRIV, $r = .48$, DEF, $r = .43$, and HAZ, $r_{pb} = -.43$. Word score moderately correlated ($p < .001$) with GLOB, $r = .48$, ACC, $r = .46$, DRIV, $r = .45$, DEF, $r = .45$, POI, $r_{pb} = .38$, and HAZ, $r_{pb} = -.33$. Smaller correlations were found between color score ACC, $r = .32$, $p < .001$, GLOB, $r = .29$, $p < .001$, DRIV, $r = .25$, $p < .01$, HAZ, $r = -.16$, $p < .05$, and POI, $r_{pb} = -.01$, $p > .05$.

On AMT, strongest correlations ($p < .001$) were total score and ACC, $r = .58$, GLOB, $r = .57$, and DRIV, $r = .54$, as well as clench extend score and GLOB, $r = .51$, and ACC, $r = .50$. Moderate correlations ($p < .001$) were obtained for most AMT and driving scores. Examples include palm up/palm down with ACC, $r = .48$, GLOB, $r = .46$,

DRIV, r = .41 and DEF, r = .39 and clench/extend with DRIV, r = .48, DEF, r = .44, and HAZ, r_{pb} = -.38. Weak correlations ($p < .01$ to $p < .001$) , under .29 included palm up/palm down with POI, tapping with HAZ and POI, and clench/extend and POI.

General Verbal Ability. VOC was strongly correlated ($p < .001$) with ACC, r = .52, and GLOB, r = .52, moderately correlated ($p < .001$) with DRIV, r = .49, DEF, r = .46, and HAZ, r_{pb} = -.43, and weakly correlated with POI, r_{pb} = -.29.

Immediate Memory. Correlations between DSF were weak with all six driving measures. They were all under .29 ($p < .01$ to $p < .001$) . DSB was moderately correlated ($p < .001$) with ACC, r = .43, GLOB, r = .43, DRIV, r = .39, DEF, r = .38, and HAZ, r_{pb} = -.33. Both DSF and DSB were very weakly correlated with POI, r_{pb} = -.06, $p > .05$, r_{pb} = -.18, $p < .05$.

Verbal Memory. Driving rating scores ACC, GLOB, DEF and DRIV were generally highly correlated with most CVLT measures. ACC and GLOB correlated equal to or above a correlation of .60 ($p < .001$) with all CVLT measures except free and cued recall intrusions. DEF and DRIV correlated equal to or above a correlation of .50, ($p < .001$) with all CVLT measures except the two intrusion scores. Both free and cued recall intrusion errors produced smaller correlations with the six driving measures ranging from r = .10, $p > .05$ to r = .36, $p < .001$. HAZ correlated above .50 ($p < .001$) with immediate recall list 1, lists 1-5 total short and long delay free recall, and correlated above .40 with ($p < .001$) with short and long delay cued recall. Smaller correlations were found for POI and the CVLT scores, ranging from r_{pb} = .09, $p > .05$, to r_{pb} = -.30, $p < .001$.

With regard to the CVMT, d-prime was most strongly correlated ($p < .001$) with driving measures DRIV, r = .55, ACC, r = .55, GLOB, r = .55, and moderately correlated ($p < .001$) with DRIV, r = .43, GLOB, r = .43, DEF, r = .37, DRIV, r = .43 ,and ACC, r = .42. Weak correlations included false alarm score with all driving measures ranging from r = .05 to r = -.27 ($p > .05$ to $p < .01$) . POI appeared to be poorly associated with CVMT scores varying from r = .05 to r = -.22 ($p > .05$ to $p < .01$) .

In general, REY-I and REY-D strongly correlated ($p < .001$) with most driving scores which included REY-I with ACC, $r = .64$, GLOB, $r = .64$, DRIV, $r = .59$, DEF, $r = .58$ and HAZ, $r_{pb} = -.51$. REY-D with ACC, $r = .64$, GLOB, $r = .64$, DRIV, $r = .59$, DEF, $r = .57$, and HAZ, $r_{pb} = -.51$. POI was weakly correlated ($p < .001$) with REY-I, $r_{pb} = -.29$ and REY-D, $r_{pb} = -.28$.

Visual-Spatial Skills. On visual-spatial and visual-constructional tasks, BLOC was strongly correlated ($p < .001$) with ACC, $r = .68$, GLOB, $r = .69$, DRIV, $r = .65$, and DEF, $r = .60$, and moderately correlated with HAZ, $r_{pb} = -.48$, $p < .001$. REY-C also strongly correlated ($p < .001$) with ACC, $r = .62$, GLOB, $r = .62$, DRIV, $r = .58$, and DEF, $r = .55$. PICT strongly correlated ($p < .001$) with ACC, $r = .66$, GLOB, $r = .65$, DRIV, $r = .60$, and DEF $r = .56$. Weaker correlations included REY-C and HAZ, $r_{pb} = -.30$, $p < .001$, BLOC and POI, $r_{pb} = -.27$, $p < .001$, PICT and POI, $r_{pb} = -.21$, $p < .05$ and REY-C and POI, $r_{pb} = -.12$, $p > .05$.

Motor Skills. FTT dominant hand score was strongly correlated ($p < .001$) with GLOB, $r = .52$, DRIV, $r = .52$, and ACC, $r = .50$, and moderately correlated ($p < .001$) with GLOB, $r = .46$, ACC, $r = .44$, DRIV, $r = .45$, and DEF, $r = -.42$. Weak correlations were obtained for HAZ and POI for both dominant and non-dominant hands, which ranged from $r_{pb} = -.22$ to $r_{pb} = -.28$ ($p < .01$ to $p < .001$) .

Table A-1

Correlations of Neuropsychological and Driving Performance for all Subjects (N=192)

Variable	Driving measures					
	HAZ	POI	ACC	GLOB	DEF	DRIV
Attention						
Trails Making Test A	.24**	.18*	-.62***	-.63***	-.60***	-.57***

Orientation	-.45***	-.22**	.55***	.53***	.43***	.48***
Executive Functioning						
Stroop Color and Word Test						
Color	-.16*	-.01	.32***	.29***	.20**	.25**
Word	-.38***	-.33***	.46***	.48***	.45***	.45***
Color-word	-.43***	-.21**	.51***	.51***	.43***	.48***
Trails Making Test B	.53***	.35***	-.73***	-.73***	-.61***	-.68***
Alternating Movements Test						
Palm up/palm down	-.32***	-.22**	.48***	.46***	.39***	.41***
Clench/extend	-.38***	-..23**	.50***	.51***	.44***	.48***
Tapping	-.24**	-.29***	.36***	.37***	.33***	.36***
Total	-.40***	-.32***	.58***	.57***	-49***	.54***
General Verbal Ability						
Vocabulary	-.43***	-.29***	.52***	.52***	.46***	.49***
Immediate Memory						
Digit Span-Forward	-.21**	-.06	.28***	.29***	.28***	.25**
Digit Span-Backward	-.33***	-.18*	.43***	.43***	.38***	.39***
Verbal Memory						
California Verbal Learning Test						
Immediate recall list 1	-.54***	-.28***	.64***	.61***	.54***	.55***
Lists 1-5 (total)	-.55***	-.30***	.65***	.64***	.56***	.58***
Short delay free recall	-.53***	-.26***	.62***	.60***	.51***	.53***
Short delay cued recall	-.48***	-.27***	.61***	.60***	.52***	.54***
Long delay free recall	-.52***	-.26***	.64***	.62***	.54***	.54***
Long delay dued recall	-.49***	-.24***	.62***	.60***	.51***	.53***
Free recall intrusions	.24**	.10	-.33***	-.30***	-.24**	-.26**
Cued recall intrusions	.36***	.09	-.38***	-.36***	.29***	-.31***

Visual Memory						
Continuous Visual Memory Test						
Hits	-.31***	-.22**	.42***	.43***	.37***	.43***
D-prime	.43***	-.21**	.55***	.55***	.47***	.55***
False alarms	.19**	.05	-.28***	-.27**	-.23**	-.22*
Total	-.39***	-.19**	.54***	.55***	.47***	.55***
Rey Osterrieth Complex Figure Recall Test						
Immediate	-.51***	-.29***	.64***	.64***	.58***	.59***
Delayed	-.51***	-.28***	.64***	.64***	.57***	.59***
Visual-Spatial Skills						
Rey Osterrieth - Copy	-.30***	-.15*	.62***	.62***	.55***	.58***
Block Design	.48***	-.28***	.68***	.69***	.60***	.65***
Picture Completion	-.43***	-.21**	.66***	.65***	.56***	.60***
Motor Skills						
Finger Tapping Test						
Dominant Hand	-.31***	-.26***	.52***	.56***	.54***	.57***
Non-Dominant Hand	-.30***	-.27**	.46***	.49***	.48***	.49***

Note. HAZ = Hazard Points/Fail, POI = Points Pass Fail, ACC = Accident Rating, GLOB = Global Rating Score, DEF = Defensive Driving, and DRIV = Driver Skill Rating.

Point-Biserial Correlation Coefficients calculated for HAZ and POI, Pearson-Product Moment Correlation Coefficients calculated for ACC, GLOB, DEF, and DRIV.

*($p < .05$), ** ($p < .01$), *** ($p < .001$), two-tailed.

Cognitively Impaired Group

Correlations between the neuropsychological and driving variables for the cognitively impaired group are shown in Table A-2.

Attention. On measures of attention, strong correlations ($p < .001$) were TMTA with GLOB, $r = -.53$, ACC, $r = -.51$, DEF, $r = -.51$, and DRIV, $r = -.45$. Moderate, but still significant correlations were also obtained for ORIENT with ACC, $r = .32$, $p < .01$, GLOB, $r = .28$, $p < .01$, DEF, $r = .18$, $p < .05$, and DRIV, $r = .25$, $p < .01$. Neither TMTA or ORIENT significantly correlated with HAZ or POI ($p > .05$) .

Executive Functioning. With regard to executive functioning, TMTB was strongly correlated ($p < .001$) with ACC, $r = -.52$ and moderately correlated ($p < .001$) with GLOB, $r = -49$, DRIV, $r = -.45$ and DEF, $r = .37$, and weakly correlated with POI, $r_{pb} = .19$, $p < .05$.

For STROOP measures, smaller but still significant correlations ($p < .05$) were observed between Color-word with ACC, $r = .24$, GLOB, $r = .22$, and DRIV, $r = .23$. Correlations between Color-word with POI and DEF did not reach statistical significance ($p > .05$) . Color score failed to reach the .05 significance level with any driving variable ($p > .05$) . Word score weakly correlated with all driving measures ranging from $r_{pb} = -.01$, $p > .05$, to $r = .23$, $p < .05$.

Moderate to weak correlations were obtained for AMT and driving scores. Moderate correlations ($p < .001$) were obtained between total score and ACC, $r = .42$, GLOB, $r = .41$, DEF, $r = .35$ and DRIV, $r = .35$. POI, $r_{pb} = -.22$, $p < .05$, and HAZ, $r_{pb} = -.17$, $p > .05$, were weakly correlated to total score. Palm up/palm down score moderately correlated with ACC, $r = .36$, $p < .001$, and GLOB, $r = .33$, $p < .001$. Weak correlations were obtained for Palm up/palm down score with DEF, $r = .26$, $p < .05$ and DRIV, $r = .25$, $p < .05$. Clench/extend score moderately correlated with DRIV, $r = .35$, $p < .001$, GLOB, $r = .34$, $p < .001$, ACC, $r = .32$, $p < .01$, and weakly correlated with HAZ, $r_{pb} = -.20$, $p < .05$ and POI, $r_{pb} = -.15$, $p > .05$. Tapping was weakly associated with all driving measures ranging from $r_{pb} = -.09$ to $r = .28$.

General Verbal Ability. On the task of verbal ability, VOC correlated between .20 and .29 with ACC, GLOB, DRIV, and DEF ($p < .05$ to $p < .01$) . Correlations between

VOC with HAZ or POI did not reach statistical significance ($p > .05$) .

Immediate Memory. The correlations between DSF, the measure of immediate memory, with the six driving measures did not reach statistical significance ($p > .05$) . DSB weakly correlated with ACC, GLOB, DRIV, and DEF. Their correlations ranged from $r = .19$, $p < .05$ to $r = .28$, $p < .01$. DSB failed to significantly correlate with HAZ or POI ($p > .05$) .

Verbal Memory. With regard to CVLT and driving performance, moderate to weak correlations were obtained. Immediate recall list 1 and lists 1-5 total scores moderately correlated with the four driver rating errors ranging from $r = .30$, $p < .01$, to $r = .38$, $p < .001$. Other moderate correlations included ACC with short, $r = .31$, $p < .01$, and long delay, $r = .35$, $p < .001$, as well as long delay cued recall, $r = .30$, $p < .01$. GLOB was moderately correlated with long delay free recall $r = .31$, $p < .01$. All other correlations between CVLT scores and driving were weakly correlated ranging from $r = .01$ $p > .05$ to $r = .29$ $p < .05$. In particular , HAZ and POI driving measures also weakly correlated with all CVLT scores, ranging from $r_{pb} = .00$ $p > .05$ to $r_{pb} = -.25$, $p < .05$, and free and cued recall intrusion scores failed to significantly correlate with any driving measure ($p > .05$) .

Visual Memory. On CVMT, D-prime moderately correlated ($p < .001$) with GLOB, $r = .47$, ACC, $r = .46$, DRIV, $r = .44$ and DEF, $r = .41$, and weakly correlated with HAZ. $r_{pb} = -.23$, $p < .05$. Slightly lower, but still moderate correlations ($p < .001$) were found between hits score with GLOB, $r = .39$, ACC, $r = .38$, DRIV, $r = .37$, and DEF, $r = .33$. Total score moderately correlated $p < .001$ with GLOB, $r = .30$, DEF, $r = .31$, and ACC, $r = .37$. False alarm score was not significantly correlated with any driving measure ($p > .05$) . POI failed to be significantly correlated to any CVMT score ($p > .05$) .

REY-I significantly correlated ($p < .001$) with ACC, $r = .41$, GLOB, $r = .43$, DEF, $r = .40$, and DRIV, $r = .42$. Moderate correlations ($p < .001$) were also obtained for REY-D with ACC, $r = .40$, GLOB, $r = .41$, DEF, $r = .37$, and DRIV, $r = .40$. Both HAZ and POI weakly correlated with REY-I and REY C ($p > .05$ to $p < .05$) .

Visual-Spatial Skills. On tasks of visual-spatial and visual-constructional abilities, both REY-C and BLOC were correlated with many driving measures. REY-C was strongly correlated (p <.001) with ACC, r = .51, GLOB, r = .51, and moderately correlated (p < .001) with DEF, r = .44, and DRIV, r = .48. BLOC significantly correlated with ACC, r =.53, GLOB, r =.53, DEF, r = .46, and DRIV, r = .49. On the other non-verbal measure, PICT, moderately correlated (p < .001) with ACC, r = .49, GLOB, r = .48, DEF, r = .40, and DRIV, r =.42. HAZ and POI weakly correlated with all three visual-spatial measures (p > .05 to p < .05) .

Motor Skills. On FTT, moderate correlations (p < .001) for the dominant hand included ACC, r = .37, GLOB, r = .33, DEF, r = .47, and DRIV r = .44. Non-dominant hand FTT scores correlated moderately with ACC, r = .31, p < .01, GLOB, r = .37, p < .001, DEF, r = .39, p < .001, and DRIV, r =.36, p < .01. Both FTT dominant and non-dominant scores were weakly correlated with HAZ and POI ranging from r_{pb} = -.07, p > .05 to r_{pb} = -.23, p < .05.

Table A-2

Correlations of Neuropsychological Tests and Driving Performance in the Cognitively Impaired Group (n=112)

Variable	Driving measures					
	HAZ	POI	ACC	GLOB	DEF	DRIV
Attention						
Trails Making Test A	-.07	.06	-.51***	-.53***	.51***	-.45***
Orientation	-.14	-.06	.32**	.28**	.18*	.25**
Executive Functioning						
Stroop Color and Word Test						

Color	.03	.09	.17	.13	.04	.12
Word	-.01	-.19	.16	.21*	.23*	.19*
Color-Word	-.10	-.01	.24*	.22*	-.13	.23*
Trails Making Test B	.12	.19*	-.52***	-.49***	-.37***	-.45***
Alternating Movements Test						
Palm up/Palm down	-.10	-.11	.36***	.33***	.26**	.25**
Clench/Extend	-.20*	-.15	.32**	.34***	.28**	.35***
Tapping	-.09	-.23*	.28**	.28**	.27**	.24**
Total	-.17	-.22*	.42***	.41***	.35***	.37***
General Verbal Ability						
Vocabulary	-.08	-.10	.29**	.28**	.22	.24
Immediate Memory						
Digit Span-Forward	.01	.06	.11	.13	.16	.11
Digit Span-Backward	-.07	-.05	.28**	.26**	-.19*	.24*
Verbal Memory						
California Verbal Learning Test						
Immediate Recall List 1	-.24*	-.09	.37***	.36***	.30**	.33***
Lists 1-5 (Total)	-.21*	-.09	.38***	.37***	.30**	.32***
Short Delay Free Recall	-.15	.01	.31**	.28**	.20*	.22*
Short Delay Cued Recall	-.05	-.05	.29**	.29**	.25**	.26**
Long Delay Free Recall	-.15	.01	.35***	.31**	.24*	.23*
Long Delay Cued Recall	-.09	-.08	.30**	.27**	.22*	.20*
Free Recall Intrusions	-.03	-.05	-.09	-.05	.01	-.01
Cued Recall Intrusions	.09	-.09	-.12	-.08	-.02	-.04
Visual Memory						
Continuous Visual Memory Test						
Hits	-.17	-.13	.38***	.39***	.33***	.37***

D-Prime	-.23*	-.06	.46***	.47***	.41***	.44***
False Alarms	-.05	-.08	-.02	-.01	-.01	.01
Total	-.12	-.05	.37***	.36***	.31**	.33***
Rey-Osterrieth Complex Figure Recall Test						
Immediate	-.19*	-.16	.41***	.43***	.40***	.42***
Delayed	-.18	-.14	.40***	.42***	.37***	.40***
Visual-Spatial Skills						
Rey-Osterreith - Copy	-.03	-.01	.51***	.51***	.44***	.48***
Block Design	.18	-.15	.53***	.53***	.46***	.49***
Picture Completion	-.10	-.07	.49***	.48***	.40***	.42***
Motor Skills						
Finger Tapping Test						
Dominant Hand	-.07	-.23*	.37***	.43***	.47***	.44***
Non-Dominant Hand	-.10	-.23*	.32**	.37***	.39***	.36***

Notes: HAZ=Hazard Points/Fail, POI=Points Pass Fail, ACC=Accident Rating, GLOB=Global Rating Score, DEF= Defensive Driving and DRIV=Driver Skill Rating

Point Biserial Correlation Coefficients calculated for HAZ and POI, Pearson-Product Moment Correlation Coefficients calculated for ACC, GLOB, DEF and DRIV

* ($p<.05$), two-tailed

** ($p<.01$), two-tailed

*** ($p<.001$), two-tailed

The intercorrelations of the driving measures in the CIG indicated that ACC, GLOB, DEF, and DRIV were strongly correlated with each other above $r = .80$. HAZ and POI were moderately correlated with one another, and with the other driving measures above $r = .30$. Table A-3 presents the driving intercorrelations for the CIG.

Table A-3

Intercorrelations of the Driving Measures in the Cognitively Impaired Group (n=112)

	Driving measures***					
	HAZ	POI	ACC	GLOB	DEF	DRIV
HAZ	----	.35	-.38	-.39	-.34	-.38
POI	.35	----	-.34	-.36	-.35	-.32
ACC	-.38	-.34	----	.97	.82	.82
GLOB	-39	-.36	.97	---	.93	.92
DEF	-.34	-.35	.82	.93	---	.84
DRIV	-.38	-.38	.82	.92	.84	---

Notes. HAZ = Hazard Points/Fail, POI = Points Pass Fail, ACC = Accident Rating, GLOB = Global Rating Score, DEF = Defensive Driving, and DRIV = Driver Skill Rating.

Point-Biserial Correlation Coefficients calculated for HAZ and POI, Pearson-Product Moment Correlation Coefficients calculated for ACC, GLOB, DEF, and DRIV.

---- = a correlation coefficient could not be printed.

*** All intercorrelations $p < .0001$.

Older Adult Control Group

Table A-4 presents correlations between neuropsychological and driving scores for the older adult control group. Overall, much lower correlations were obtained compared to CIG or total subjects. Moderate correlations included TMTB with DRIV, $r = -.36$, $p < .05$, REY-C with GLOB, $r = .30$, $p < .05$, and ACC, $r = .31$, $p < .05$, BLOC with DRIV, $r = .31$, $p < .05$, FTT dominant hand score with GLOB, $r = .31$, $p < .05$, and DRIV, $r = .49$, $p < .001$, and non-dominant hand score with DRIV, $r = .41$, $p < .01$. All other correlations

were weak and most failed to reach the .05 significance level.

Table A-4

Correlations of Neuropsychological Tests and Driving Performance in the Older Adult Control Group (n=50)

Variable	Driving measures					
	HAZ	POI	ACC	GLOB	DEF	DRIV
Attention						
Orientation	—	.10	-.03	-.05	-.04	-.03
Trail Making Test A	—	-.12	-.01	.00	.12	-.14
Executive Functioning						
Stroop Color and Word Test						
Color	—	-.05	.14	.09	.00	.05
Word	—	-.07	-.08	.00	.01	.17
Color-word	—	-.02	.26	.26	.16	.22
Trail Making Test B	—	-.03	-.20	-.26	.17	-.36*
Alternating Movements Test						
Palm up/palm down	—	-.15	-.01	.00	-.08	.11
Clench/extend	—	-.02	.23	.22	.15	.14
Tapping	—	-.28	.14	.12	-.10	.28
Total	—	-.17	.21	.19	.03	.24
Immediate Memory						
Digit Span-Forward	—	.07	-.03	-.11	-.16	-.14
Digit Span-Backward	—	.02	-.06	-.07	-.02	-.12

Verbal Memory

California Verbal Learning Test

Immediate recall list 1	----	-.23	.15	.07	-.04	-.11
Lists 1-5 (total)	----	-.25	.02	.00	-.06	.07
Short delay free recall	----	-.25	-.01	-.03	.02	-.12
Short delay cued recall	----	-.20	.10	.03	-.01	-.10
Long delay free recall	----	-.22	.13	.10	.14	-.08
Long delay cued recall	----	-.18	.07	.02	-.04	-.04
Free recall intrusions	----	.09	.11	.05	-.05	.00
Cued recall intrusions	----	.09	.07	.06	.05	-.01

Visual Memory

Continuous Visual Memory Test

Hits	----	-.21	-.20	-.14	-.16	.12
False alarms	----	-.13	-.10	-.09	-.16	.07
D-prime	----	-.14	-.13	-.11	-.21	.15
Total	----	.02	.00	.03	.11	-.02

Rey Osterrieth Complex Figure Recall Test

Immediate	----	.16	.20	.20	.22	.07
Delayed	----	.10	.18	.18	.18	.06

Visual-Spatial Skills

Rey Osterrieth - Copy	----	.10	.31*	.30*	.25	.13
Block Design	----	-.05	.24	.25	.12	.31*
Picture Completion	----	.23	.28	.20	-.02	.16

Motor Skills

Finger Tapping Test

Dominant hand	----	.17	.20	.31*	.24	.49***
Non-dominant hand	----	.07	.13	.23	.17	.41**

Notes. HAZ = Hazard Points/Fail, POI = Points Pass Fail, ACC = Accident Rating, GLOB = Global Rating Score, DEF = Defensive Driving, and DRIV = Driver Skill Rating.

Point-Biserial Correlation Coefficients calculated for HAZ and POI, Pearson-Product Moment Correlation Coefficients calculated for ACC, GLOB, DEF, and DRIV.

---- = a correlation coefficient could not be printed.

*($p < .05$), ** ($p < .01$),*** ($p < .001$), two-tailed.

Younger Adult Control Group

Similar to OCG, very few moderate correlations were obtained and even less reached statistical significance at the .05 significance level. Significant moderate correlations ($p < .05$) included color score of the STROOP with POI, $r_{pb} = .44$, ACC, $r = .44$, and GLOB, $r = .39$, and word score with POI, $r_{pb} = .40$, $p < .05$. D-prime of the CVMT moderately correlated with DEF, $r = -.39$, $p < .05$. Table A-5 summarizes the correlations of neuropsychological and driving measures for the younger control group.

Table A-5

Correlations of Neuropsychological and Driving performance in the Younger Adult Control Group (n=30)

Variable	Driving measures					
	HAZ	POI	ACC	GLOB	DEF	DRIV
Attention						
Orientation	----	.07	-.03	.02	.05	.07
Trails Making A	----	-.14	-.03	-.06	-.07	-.08
Executive Functioning						
Stroop Color and Word Test						

Color	----	.44*	.44*	.39*	.36	-.04
Word	----	.40*	-.21	-.08	-.10	.03
Color-word	----	-.15	.07	.14	.28	.00
Trails Making B	----	.00	-.10	-.21	-.20	-.28
Alternating Movements Test						
Palm up/palm down	----	----	----	----	----	----
Clench/extend	----	.05	.09	-.02	-.14	-.10
Tapping	----	.05	.06	.23	.33	.26
Total	----	----	----	----	----	----
General Verbal Ability						
Vocabulary	----	.03	-.06	-.05	-.04	.01
Immediate Memory						
Digit Span-Forward	----	-.03	.23	.31	.34	.15
Digit Span-Backward	----	.00	.09	.23	.35	.16
Verbal Memory						
California Verbal Learning Test						
Immediate recall list 1	----	.25	-.02	.03	.03	.17
Lists 1-5 (total)	----	-.14	-.10	-.04	-.06	.01
Short delay free recall	----	-.07	.16	-.15	-.14	-.01
Short delay cued recall	----	.01	-.31	-.31	-.19	-.19
Long delay free recall	----	-.11	-.10	-.05	-.05	-.01
Long delay cued recall	----	-.11	-.13	-.09	-.01	-.04
Free recall intrusions		-.01	-.29	-.33	-.20	-.29
Cued recall intrusions	----	.25	.19	.12	.15	.19
Visual Memory						
Continuous Visual Motor Test						
Hits	----	.08	.13	-.20	-.26	-.12

False alarms	-----	.01	.00	.02	.15	-.10
D-prime	-----	.00	-.18	-.26	-.39*	-.04
Total	-----	.03	-.09	-.10	-.23	.13
Rey Osterrieth Complex Figure Recall Test						
Immediate	-----	-.09	.06	.02	-.07	.03
Delayed	-----	.01	.04	.06	.02	.10
Visual-Spatial Skills						
Rey Osterrieth Copy Test	-----	-.10	.13	.06	.08	-.18
Block Design	-----	-.30	.10	.20	.16	.28
Picture Completion	-----	.08	.07	.14	.16	.15
Motor Skills						
Finger Tapping Test						
Dominant hand	-----	.30	.32	.21	.11	.17
Non-dominant hand	-----	.28	.12	.08	.05	.07

Note. HAZ = Hazard Points/Fail, POI = Points Pass Fail, ACC = Accident Rating, GLOB = Global Rating Score, DEF = Defensive Driving, and DRIV = Driver Skill Rating. Point-Biserial Correlation Coefficients calculated for HAZ and POI, Pearson-Product Moment Correlation Coefficients calculated for ACC, GLOB, DEF, and DRIV.

*($p < .05$), ** ($p < .01$), *** ($p < .001$), two-tailed.